Radio, Electronics and Communications

FORMERLY "RADIO & ELECTRICAL REVIEW" — WIDELY KNOWN SINCE 1946 AS "R. & E."

MPL

In This Issue . . .

- Field Effect Transistors.
- The ionosphere and H.F. Transmissions.
- Frequency engineering for V.H.F. mobile services.
- Investigations of V.L.F. propagation.
- Laboratory Report; Conference News.

PUBLISHED MONTHLY IN THE INTERESTS OF THE N.Z. ELECTRONICS INDUSTRY FOR ALL LEVELS, FROM PROFESSIONAL TO AMATEUR.

VOLUME 21 NUMBER 5

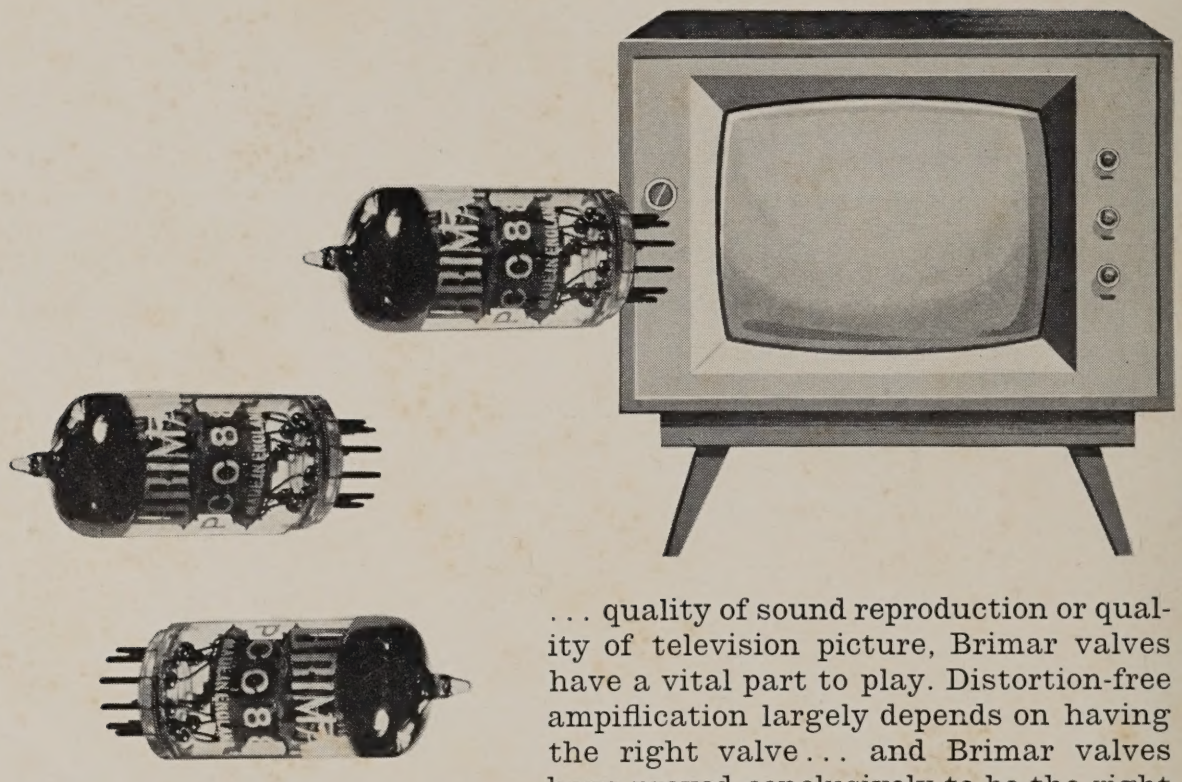
JULY 1, 1966

PRICE 2/6

ANOTHER NEW PRODUCT FROM AWA—WITH EXPORT POTENTIAL

AWA

WHENEVER QUALITY COUNTS . . .



. . . quality of sound reproduction or quality of television picture, Brimar valves have a vital part to play. Distortion-free ampiflication largely depends on having the right valve . . . and Brimar valves have proved conclusively to be the right valves for today's exacting needs. When it comes to TV, Brimar Teletubes are equally 'in the picture'. No wonder Brimar valves are specified both by set manufacturers and for dealers' replacement purposes.

better rely on –

BRIMAR

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B.12

ENQUIRY 345. USE FORM AT REAR.

Compact New Universal Impedance Bridge

Fast readings with no ambiguities

This new Hewlett Packard universal impedance bridge, Model 4260A makes unambiguous measurements rapidly, having only one control to obtain a null.

Measurements of C, R. L. D (dissipation factor of capacitors), and Q may be made. The steps involved are simple: set the function knob for the parameter to be measured, adjust the range switch for an on-scale indication, and obtain a null with only the CRL dial. **Auto-balance** is the key to simplified operation. Its function is to eliminate control interactions, so a null can be obtained with one control only. The **Model 4260A** bridge is balanced in the automatic mode by phase-controlling the balance leg so it is automatically slaved to that leg which is being adjusted for null. This is done with a voltage-tuned resistor controlled by a phase detector.

Finding the null is made easy by illuminated pointers, right alongside the null-adjusting knob, which light automatically to show whether the null is to be found up-scale or down-scale. With these pointers and the auto-balance, an accurate measurement may be made in one fast easy sequence.

The readout, for C, R, and L, is digital, with the demical point automatically positioned. Units of measurement, e.g. pF and μF, are automatically shown.

The new **Hewlett-Packard Model 4260A Universal Impedance Bridge** is less than 7½" high, 7⅜" wide, and 11" inches deep. A tilt stand is provided to raise the viewing angle for bench use; the instrument may be rack-mounted with available accessory hardware. Data sheets and further information available from Sample's Auckland Laboratory. **Price £302/10/- Duty Paid,** delivery anywhere in New Zealand.

CAPACITANCE MEASUREMENT

Capacitance
- Range: 1 pF to 1000 μF, in 7 ranges.
- Accuracy:
  - $\pm$ (1% + 1 Digit), from 1 nF to 100 μF.
  - $\pm$ (2% + 1 Digit), from 1 pF to 1000 μF.
  - Residual capacitance 2 pF.

Dissipation Factor
- Range:
  - LOW D - - - D (of series C): 0.001 to 0.12.
  - HIGH D . . . D (of parallel C): 0.05 to 50.
- Accuracy:
  - LOW D . . . D (of series C): $\pm$ (5% + 0.002) or ONE DIAL DIVISION, whichever is greater.
  - HIGH D - - - 1/D (of parallel C): $\pm$ (5% + 0.05) or ONE DIAL DIVSON of LOW Q. dial, whichever is greater.

I (C greater than 100 pF.)

INDUCTANCE MEASUREMENT

Inductance
- Range: 1 μH to 1000 H, in 7 ranges.
- Accuracy:
  - $\pm$ (1% + 1 Digit), from 1 mH to 100 H.
  - $\pm$ (2% + 1 Digit), from 1 μH to 1000 H.
  - Residual inductance $<$ 1 μH.

Quality Factor
- Range:
  - LOW Q - - - Q (of series L): 0.02 to 20.
  - HIGH Q - - - Q (of parallel L): 8 to 1000.
- Accuracy:
  - LOW Q - - - Q (of series L): $\pm$ (5% + 0.05) or ONE DIAL DIVISION, whichever is greater.
  - HIGH Q - - - -/Q (of parallel L): $\pm$ (5% + 0.002) or ONE DIAL DIVISION of LOW D dial, whichever is greater.
  - (L greater than 100 μH.)

RESISTANCE MEASUREMENT

Range: 10 milliohms to 10 megohms, in 7 ranges.

Accuracy:
- $\pm$ (1% +1 Digit), from 10 ohms to 1 megohm.
- $\pm$ (2% + 1 Digit), from 10 milliohms to 10 megohms.
- Residual resistance 3 milliohms.
- Resistance measurements at DC only.

Electronic Auto Null: Eliminates need for DQ adjustments in parallel C and series L measurements at 1 kc.
- Accuracy (when D $\leq$ 1, Q $\geq$ 1 and CL measurements are made in 3 and 4 figures) equals [normal operating condition $\pm$ 0.5%].

OSCILLATOR AND DETECTOR

Internal Oscillator: 1 kc $\pm$ 2%, 100 mV rms $\pm$ 20%.

Internal Detector: Tuned amplifier at 1 kc; functions as a preamplifier for measurements with external generator.

External Oscillator: 20 Hz to 20 kHz measurements of capacitance, inductance, dissipation factor and quality factor are possible with external oscillator (range will be a function of applied frequency).

SAMPLE ELECTRONICS (N.Z.) LTD.
8 Matipo St., Onehunga, Auck., S.E.5., Phone:- 567-356

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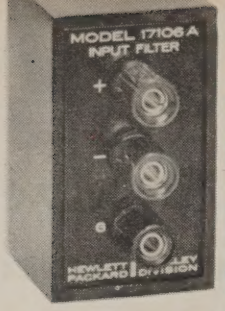
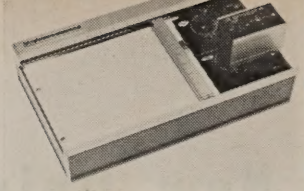


Input filters for strip-chart recorders to reject power line frequencies

Power line frequencies (50 Hz) are rejected by more than 60 dB when new direct-mating filters are connected to Moseley strip-chart recorders.

Inserted in series with the input of **Model 7100B** and **7127A** series dc strip-chart recorders from the **Moseley Division** of **Hewlett-Packard**, these new filters greatly reduce the error-producing effects of noise superimposed on the measured signal. The external filters are compatible with the **17500A** and **17501A** input modules. The **17106A** mates with the front panel input, while the **17107A** is used with the modules' rear input connector. Both contain the same circuitry, a twin "T" and low-pass filter, factory-tuned for maximum rejection of 50 Hz signals, as desired. They have no effect upon the accuracy of the recorder, when installed according to smiple procedures. Input signals up to 200 v may be applied.

Model 17106A and 17107A Input Filters are priced at £19/5/- each duty paid. Delivery: 3 weeks from Sample Electronics to anywhere in New Zealand.



Self-contained time base adds automatic sweep to X-Y recorders

Automatic sweep is conveniently added to **Moseley** X-Y recorders with a small, self-contained time-base from **Hewlett-Packard's Moseley Division**. Generating a ramp voltage, linear to 0.5%, the new **Model 17108A** External Time Base plugs directly into **Model 7035A** recorders, and is readily adapted to other Moseley models. Five calibrated sweep speeds are available, from 0.5 to 50 seconds per inch.

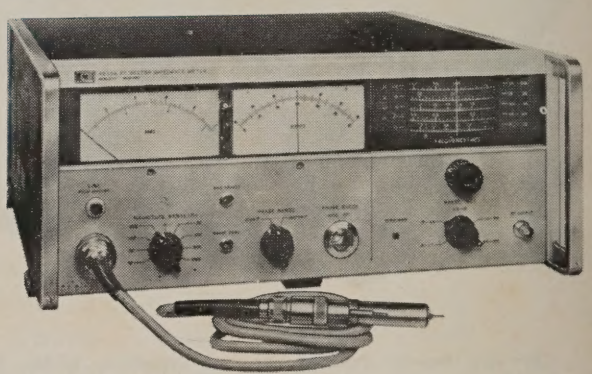
Model 17108A measures only $4\frac{3}{8}$" x $2\frac{1}{2}$" x $3\frac{3}{4}$", completely self-contained, including the battery, which provides a minimum of 100 hours operation.

The new Moseley time bas will drive any number of X-Y recorders simultaneously, provided only that hhe combined impedance seen by the Time Base output is greater than 20,000 ohms.

The linear ramp output of the Time Base ends at 1 volt minimum. PRICE: £96/5/-. Duty paid, delivered anywhere in New Zealand.

Single Instrument Measures Impedance anc phase, 500 kHz to 108 MHz, with one probe

The H.P. 4815A RF Vectar-Impedance Meter



The complex impedance of any circuit element or component is measured in a single test by a single probe, with the **4815A**. Over the frequency range 500 kHz to 108 MHz, the instrument presents impedance directly in ohms on one front-panel meter, phase angle directly in degrees on another. A single thin probe excites the test element, and simultaneously measures its impedance and its phase angle. No supplementary equipment is required.

An internal oscillator supplies a low-level exciting signal through a five foot cable to the probe; a unique sampling AGC loop maintains the current constant at 4 microamperes. At the same time, the voltage response of the tested element is sensed and converted by a second sampling channel, located within the same probe, to read out directly in impedance. A phase detector monitors the difference between voltage and current channels, to yield the phase angle of the impedance vector.

The built-in continuous-tuning oscillator; frequency displayed clearly alongside the read out, requires no balancing or data interpretation; it has controls only for band and frequency.

Impedance range is 10 ohms to 100,00 ohms; phase angle range is 0 to 360° in 2 ranges, 0 ±90°, and 180° ±90°. Resolution is better than 2°.

Accuracy for frequency, ±2% of reading; ±1% of reading at 1.592 and 15.92 MHz. For impedance, it is ±4% of full scale

$$\pm\left(\frac{F}{30\ \text{MHz}} + \frac{Z}{35{,}000\Omega}\right)\%$$ of reading, where F is the frequency in MHz and Z is in ohms; the reading includes probe residual impedance.

Accuracy for phase angle measurements is—

$$\pm\left(3 + \frac{F}{30\ \text{MHz}} + \frac{Z}{50{,}000\Omega}\right)^\circ$$

The 4815A may be swept by an external sweep oscillator at rates up to 1 MHz per second. Analog outputs are provided for frequency and phase angle, for convenient recording on an X-Y recorder.

A front-panel monitor from the internal oscillator may be fed to a frequency counter

Front panel RF output provides at least 150 villivolts into 50 ohms over full frequency range tuned.

Front panel test point delivers a normalized impedance reading of 100 ohms at a phase angle of 0°, when the probe is inserted.

The instrument will directly measure inductance and capacitance, as well as impedance.

When the frequency dial is set either to 1.592 or 15.92 MHz, the impedance magnitude meter reads directly in the numerical value of L or $\frac{1}{C}$, while range and frequency determine the decimal point.

Values of C as high as 0.1μF and of L to 10 mH may thus be measured. **Price: £1457/10/- Duty Paid, delivered anywhere in New Zealand.**

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SILICON DIODE POWER TRANSFORMERS AVAILABLE FROM BEACON RADIO LTD.

R98 T.V. POWER TRANSFORMER

For R.T.V. & H. 1959 and later T.V. Sets.
Delivers 260v @ 300mA D.C. Full wave voltage doubler.
230:115v A.C. @ 300mA D.C.
:12.6v C.T. @ 5A (2 windings ea. 6.3 @ 5A).
:0—6.3—7.5—9 @ .6A. Picture tube winding.
Choke:—C36. Use 400v P.I.V. Diodes.

R103 Stereo Power Transformer

R.T.V. & H. Aug. 60. 7w Stereo.
230:245v @ 150mA. D.C.
:104v @ 150mA D.C. Voltage doubler Rect.
:6.3v C.T. @ 5A.
Choke:—C42. Use 400v P.I.V. Diodes.

R104 Stereo Power Transformer. 10w

320v @ 320mA. Voltage doubler Rect.
230:130v @ 320mA.
:6.3v @ 6A.
Choke:—C49. Use 500v P.I.V. Diodes.

R105 T.V. Power Transformer For Philips T.V. Kitsets

220v @ 420mA D.C. Voltage Doubler Rect.
230:106v @ 420mA D.C.
:6.3v @ 10A.
:0—6.3—7.5—9 Ov @ 0.3A. Picture tube Winding.
Choke:—C45. Use 400v P.I.V. Diodes.

R106 T.V. Power Transformer for Philips T.V. Kitsets

This type similar to R105 but less Picture Tube boost taps. Main Fils. 12.6v C.T. @ 5A.
220v @ 420mA D.C. Voltage Doubler Rect.
230:106v @ 420mA D.C.
:12.6v C.T. @ 5A (2 windings 6.30v @ 5A each).
:6.3v @ .3A Picture tube winding.
Choke:—C45. Use 400v P.I.V. Diodes.

R108 Small Stereo Headphone Power Transformer

250v @ 22mA D.C.
230:110v @ 22mA D.C. Voltage doubler Rect.
:6.3 @ 0.86A.
Choke:—C41. Use 400v P.I.V. Diodes.

R110 T.V. Power Transformer. For Philips T.V. Kitsets

This transformer uses full wave bridge rectifier. Requires no limiting resistor unlike equivalent voltage double types, also has advantage of no insulated capacitor and lower ripple output with smaller choke.
Output 220v @ 420mA D.C.
230:172v @ 420mA D.C. Full wave bridge Rect:
:12.6v C.T. @ 5A (2 only 6.3v winding @ 5A).
:6.3v @ .3A Picture tube winding.
Choke:—C50. Use 400v P.I.V. Diodes.

R111 T.V. Power Transformer

Similar to R110 but for R.C.A. type Kitsets.
260v @ 350mA from Rect.
230:207v @ 350mA D.C. Full wave bridge Rect.
:12.6v C.T. @ 5A (2 only 6.3v windings each 5A).
:6.3v @ 0.6A. Picture tube winding.
Choke:—C42. Use 400v P.I.V. Diodes.

R112 Oscilloscope Power Transformer

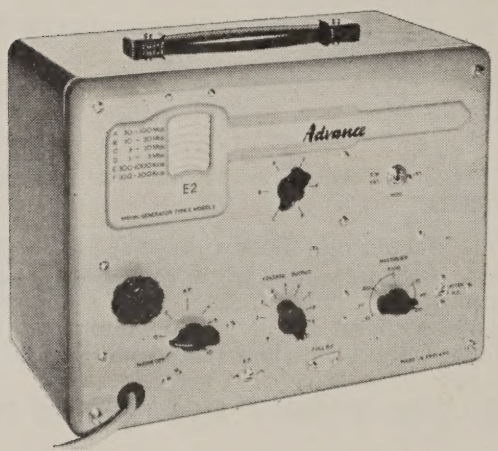
R.T.V. & H. 1963. Calibrated.
230:110v @ 80mA D.C. Full wave voltage doubler.
:6.3v @ 2.4A.
:6.3v @ 1A.
:6.3v @ 1A.
Use 400v P.I.V. Diodes.

BEACON RADIO LIMITED

Corner Brown and Fitzroy Sts., Ponsonby, Auckland. P.O. Box 2757. Telephone 12-168 (5 lines)

ENQUIRY 348. USE FORM AT REAR.

Advance r.f. signal generators

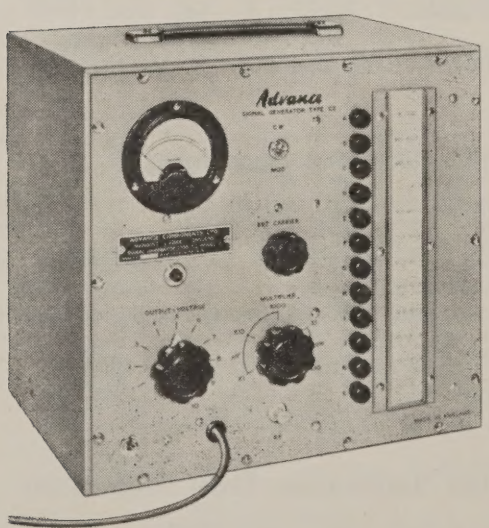


E2

R.F. Signal Generator

Frequency range 100kc/s to 100Mc/s in six bands. *Calibration accuracy* ±1%. *Output* Approximately 1V at the full R.F. socket. Continuously variable 1μV to 100mV. Accuracy of maximum output ±3dB. Accuracy of step attenuator ±(3dB + 3μV). *Output impedance* 75Ω unterminated. Normally this is matched with a 75Ω terminating pad TP1B, providing 37Ω, 10Ω and a standard 10Ω dummy aerial. *Modulation* INTERNAL 30% ±5% at 400c/s ±10%. EXTERNAL 0 to 80%, 10c/s to 4kc/s; 0 to 40% at 10kc/s. *A.F. output* 0 to 50V, 400c/s into high impedance. *Leakage* Less than 3μV. *Power requirements* 105 to 125V and 210 to 250V, 40 to 100c/s, 20W.

Dimensions 13in (33cm) wide × 10¼in (26cm) high × 8in (20·3cm) deep.
Weight 17½lb (8kg).



C2H

R.F. Signal Generator

Frequency range Twelve spot frequencies in the range 30kc/s to 40Mc/s. *Output* Continuously variable 1μV to 100mV. *Accuracy* Below 10Mc/s, ±1dB ±1μV; 10 to 40Mc/s, ±2dB ±2μV. *R.F. level* The R.F. level between push-button settings does not vary by more than ±3%. With ±10% a.c. supply variation, the output level change will not exceed ±3%. *Output impedance* 75Ω unterminated. *Modulation* Carrier internally amplitude modulated 30% ±5% at 400c/s ±5%. *Power requirements* 100, 210, 230, 250V, 40 to 100c/s, 25W. *Dimensions* 12¼in (31cm) wide × 13¼in (33·7cm) high × 10in (25·4cm) deep. *Weight* 28lb (12·7kg).

ADVANCE ELECTRONICS LIMITED ENGLAND

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ENQUIRY 347. USE FORM AT REAR.

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* * *

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CONTENTS

	Page
Editorial	13
Investigation of sub ionospheric propagation of VLF radio signals *by G. J. Burtt*	14
Field Effect Transistors	17
Frequency engineering for VHF Mobile Services *by R. Cassey*	21
Properties of the ionosphere which affect HF transmission *by F. R. Fast*	24

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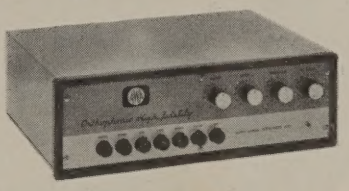
Departments . . .

Letters	9
Serviceman's Column *by J. Whitley Stokes*	29
New Products	37

On Our Cover



During the past two years, AWA's Development Laboratory in New Zealand has been working on a new range of High Fidelity Amplifiers and Broadcast Tuners. The Company has now released the AWA Orthophonic High Fidelity Solid State Stereo 40, as depicted on the front cover.

Specifications and quality of the amplifier, which excel imported equivalents, reflect credit on the engineers who have been responsible for this project. The amplifiers are now in quantity production, and supplies are being distributed to dealers. An AWA sales engineer is presently in Australia investigating the prospects of exporting there.

ENQUIRY 354. USE FORM AT REAR.

Coming . . .

- A Converter for 432 mhz
- Integrated VHF & UHF communications and telemetry bearer system
- Measuring elastic moduli and friction in rods
- TV Kitset in two parts
- Precision frequency and time standards
- A range of simple test equipment

Also . . .

Serviceman's Column
Circuit & Service Data
Listening Post
Digest of Symbols
Book Reviews

REDFERN TRANSISTOR INVERTERS

SQUARE WAVE OR SINE WAVE MODELS AVAILABLE

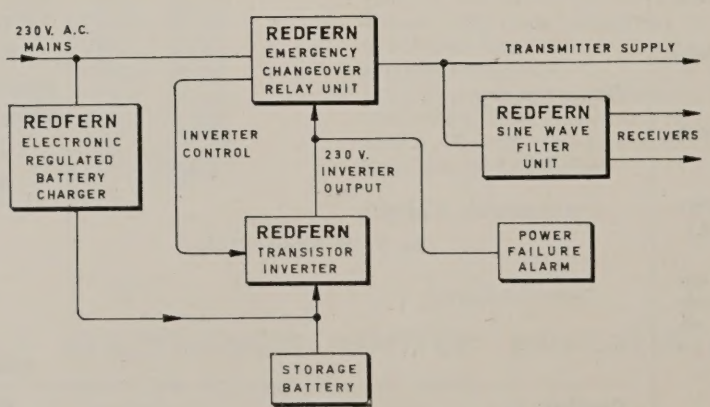
FOR EMERGENCY POWER SUPPLIES

As illustrated, 350 Watt 12V D.C. to 230V 50.CPS A.C. INVERTER Model powers ¼" Electric Hand Drill, Lamps, Soldering Irons, Electronic Equipment up to 350 Watt Power rating.

FEATURES remote control connections, frequency and drive control, load indicator lamp, twin 230V Outlets, reverse polarity protected, Start run switch with centre off fitted, operating instructions printed on front panel. Available accessories — Redfern Sine Wave Filter Regulator Unit for obtaining Sine wave outputs, emergency change-over relay unit, electronic controlled battery charger.

These units may be combined to form an emergency no-break power supply to maintain essential services during A.C. mains failure.

TYPICAL NO-BREAK SUPPLY FOR V.H.F. RADIO-TELEPHONE BASE



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REDFERN RADIO

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ENQUIRY 343. USE FORM AT REAR.

Letters from Readers

BRITISH TECHNICIAN SOCIETY NOW WELL ESTABLISHED

Recent mail brought to us from England further news of the Society of Electronic and Radio Technicians, London. This society, set up a little over a year ago now has several thousand members.

One of its main objects is the advancement of techniques and practice as applied in the industry. In Britain it holds meetings, publishes a Journal and is working in the field of technician education. In appropriate ways it has already done much to increase the status of technicians.

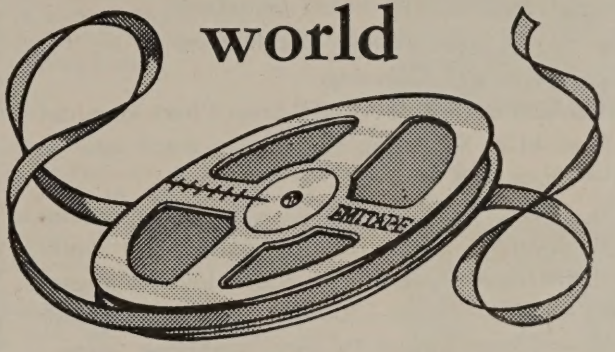
These it has all done very successfully in a short time and the response to its efforts indicates that some of its aims could be accepted in this country. The Journal contains very worthwhile articles of interest to technicians and servicemen dealing both with service techniques and new methods and components.

Further information on the Society can be obtained from

SERT Box 3381 Auckland.

ENQUIRY 356. USE FORM AT REAR.

Emitape magnetic recording tape— the finest in the world



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"77" Pen-Tested Professional
"88" Standard Play
"99" Long Play
"100" Double Play

Special EMITAPE features include:

* Anti-static
* High sensitivity
* Low 'print-through' factor
* Spool sizes for all tape recorders

MAGNETIC PROPERTIES (All grades)	PHYSICAL PROPERTIES Width (all grades): 0.246" ± .002"			
COERCIVITY: 270 Oersteds	TYPE:	77	88	99	100
RETENTIVITY: 0.6 Maxwells	Base Thickness (μ)	37.5	37.5	25.0	15.2
BACKGROUND NOISE: At least 64dB below Peak Recording Level	Coating Thickness (μ)	12.5	12.5	12.5	9.2
MODULATION NOISE: At least 56dB below Peak Recording Level	Tensile Strength (lbs)	9.0	9.0	5.5	6.0
PRINT FACTOR: At least 52dB below Peak Recording Level after storage for 72 hrs. at 65°F	Yield Point (lbs)	4.75	4.75	2.75	4.0
	Elongation at 0.5 lb load (%)	0.25	0.25	0.34	0.34
	Humidity Expansion (per 1% RH) 12 x 10⁻⁵	NEGLIGIBLE			

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EQUIPMENT EXHIBITION

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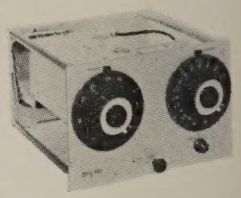
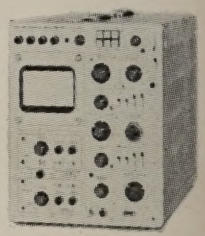
AEG — Pikapont Resistance Bridge
AEG — Silicon & Selenium Rectificers
AIRMEC — Type 257 VLF Signal Generator
AIRMEC — Type 279 Display Oscilloscope
AIRMEC — Type 391 Galvamp
BAUSCH & LOMB — Type VOM5 Strip Chart Recorder
EAI — Type 1130 X-Y Variplotter
ELCOM — Plugs and Sockets
GENERAL RADIO — Type 1551-C Sound level meter
GENERAL RADIO — Type 1565-A Sound level meter
GENERAL RADIO — Type 1552-B Sound level calibrator
GENERAL RADIO — Type 1307-A Transistor Oscillator
GRUNDIG — Closed circuit TV over telephone wires.
GRUNDIG — Grid Dip Oscillator
NIFE — Ni/Cd Rechargeable Batteries
PRECISION — Type E310 Wide Range Oscillator
PRECISION — Type 120 VOM
RACAL — Type SA520 300 Kc/s Frequency Counter.
RACAL — Type SA535 1.2 Mc/s Universal Counter/Timer
RACAL — Type SA535 B 1.2 Mc/s Universal Counter/Timer
RACAL — Type MA.38 Tacho-generator
TEKTRONIX — Type 564 Storage Oscilloscope
TEKTRONIX — Type 2A63 Differential Plug-in
TEKTRONIX — Type 2B67 Time Base Plug-in
TEKTRONIX — Type 3C66 Carrier Amplifier Plug-in
TEKTRONIX — Type 549 Storage Oscilloscope
TEKTRONIX — Type 1S1 Sampling Plug-in
TEKTRONIX — Type 1L20 Spectrum Analyser
TEKTRONIX — Type 1A7 Differential Plug-in
TEKTRONIX — Type W Differential Comparator Plug-in
TEKTRONIX — Type O Operational Amplifier Plug-in
TEKTRONIX — Type TDR Pulser
TEKTRONIX — Type 422 Portable Oscilloscope
TEKTRONIX — Type 453 Portable Oscilloscope
TEKTRONIX — Type 114 Pulse Generator
TELONIC — Type SM2000 Sweep/Signal Generator
TELONIC — Type E — IM Plug-in Head
TELONIC — Type LH-2 Plug-in Head
TELONIC — Type SV13 T.V. Sweep Generator
TELONIC — Type TG-950 Toggle Switch Attenuator
TELONIC — Type XD-23A R.F. Detector
TELONIC — Type XD-3A R.F. Detector
TELONIC — Type TS-100A Coaxial Switch
TELONIC — Type TS-200A Coaxial Switch
ULTRAKUST — Electronic Thermometers
WESTON — Model 80 VOM

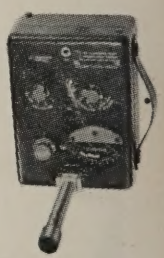
TELONIC LH-2 VIDEO PLUG-IN—is a heterodyne unit providing wide band coverage of 400 Kc/s to 110 Mc/s in a single sweep, when used with the Type SM 2000 Sweep Generator. The LH-2 is useful for test and evaluation of video and wide band amplifiers, and covers the Video and AM Radio Bands as well as navigational and Low Frequency communications.



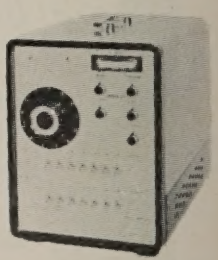
TEKTRONIX TYPE 549 STORAGE OSCILLOSCOPE—The Type 549 provides split-screen storage and accepts all 1-series and letter-series plug-ins. The vertical response is D.C. to 30 Mc/s and the time base features calibrated sweeps from 0 1 s to 5 sec in 24 steps with calibrated sweep delay from 1 s to 10 sec on time Base B. Each half of the screen can be erased.



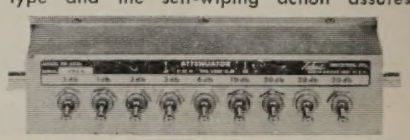
GENERAL RADIO TYPE 1551-C SOUND-LEVEL METER—an accurate, easily portable instrument that read sound-pressure level over a wide, 24-dB to 150-dB, range. It is simple to operate; sound level is indicated by the sum of meter and attenuator readings. It can be used with spectrum analysers, calibrators, and an output facility enables direct coupling to a graphic level recorder or tape recorder.



TELONIC SV13 TV SWEEP GENERATOR 20-250 Mc/s—The SV13 is designed for laboratory and production line adjustment, alignment and inspection of the R.F. channels and I.F sections of television receivers and other V.H.F. circuits. Plug-in R.F. strips to any frequencies are available and N.Z. standards are a stock item. Two marker spacings from 1 to 12 Mc/s within the 20 Mc/s sweep are optionally available.



TELONIC TG—950 TOGGLE SWITCH ATTENUATOR—These attenuators are available to provide 0 to 42 dB or 0 to 102 dB in 1 dB steps and 0 to 82.5 dB in 0.5 dB steps. Leakage is held to a minimum by double shielding each pad accuracy is assured by using 1% carbon film resistors. The switch contacts are double knife edge type and the self-wiping action assures excellent repeatability. Turnet attenuators are also available.

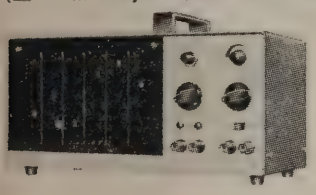


Be certain to visit McLean's stand at the Trade Exhibition during the First National Electronics Conference and see the equipment listed below demonstrated. Several representatives from our overseas principals will be there to answer your questions, and remember it is not necessary to be enrolled at the conference to visit the Trade Exhibition.

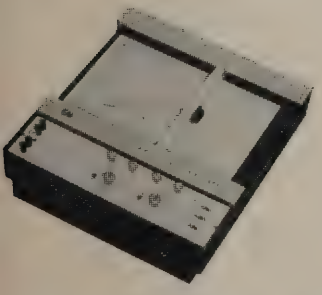
TEKTRONIX TYPE 1S1 SAMPLING UNIT—The 1S1 converts tektronix Oscilloscope to a D.C. to 1 Gc/s sampling unit. Risetime is 0.35 nsec and calibrated sweeps range from from 100 psec/cm to 50 sec/cm whilst a x 100 magnifier allows magnification of any part of the display without reducing dot density. Calibrated vertical sensitivities range from 2mV/cm to 200 mv/cm D.C. offset permits millivolt readings in the presence of up to ± 1V input levels. Also outputs are available for X-Y and strip chart recorders.

ULTRAKUST ELECTRONIC THERMOMETER—Part of an extensive range of battery operated electronic thermometers in various ranges from — 100°C to 700°C with accuracies of ± 1% Potentiometric recording types with 0.2% accuracy are also available.

RACAL MODEL SA535 1.2 Mc/s UNIVERSAL COUNTER/TIMER — Direct frequency measurement up to 1.2 Mc/s and time measurement to 10^4 secs. In steps of 1 S with accuracy of ± 1 count ∓ internal crystal stability (± 1 in 10^6) Solid state circuitry. Digital Print-out recorder facilities. Standard Output frequencies from oven controlled crystal oscillator. New type six digit column readout or IN-LINE readout version available. New type SA.548 Decade Divider Unit extends range to 15 Mc/s with same accuracy.



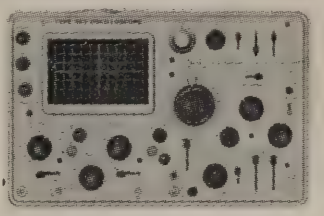
EA1 SERIES 1130 X-Y VARIPLOTTER — Calibrated Input ranges on both axes from 1mV/inch to 20V/inch in 18 ranges. A ten turn continuously variable vernier scale is also provided Recording area 10" x 15". Slewing speed 20 inches/sec on each axis. Time base ranges—calibrated sweeps at 0.5, 1, 2, 5, 10 and 20 seconds per inch with uncalibrated vernier between ranges. Accuracy — ±0.05% Resetability.



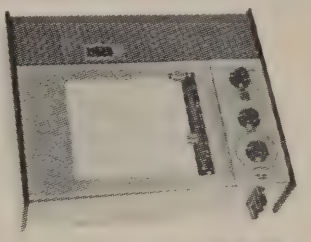
TEKTRONIX TYPE 114 PULSE GENERATOR

Less than 10-Nanosecond rise and fall time! Variable pulse period, width, and amplitude; Instant Square-Wave selection; All solid state. The new Type 114 is a general-purpose generator designed for laboratory and production test facilities. The versatility of the Type 114 makes it well suited for applications, such as medical stimulation, studying network response to changes in period and/or width, or determining the step response of systems. It can also serve as a repetition-rate generator or as a delay generator.

TEKTRONIX TYPE 453 PORTABLE OSCILLOSCOPE—The type 453 combines portability and performance previously unavailable in a D.C. to 50 Mc/s oscilloscope. Calibrated sweep range is 0.1 S/div with a X10 magnifier extending to 10nS/div. and calibrated sweep delay 1S to 50S. Vertical deflection is 5MV/div to 10V/div in 11 calibrated steps.



Bausch & Lomb VOM-5—Potentiometric Strip Chart Recorder has full scale spans of 0.01, 0.1, 1, 10, 100 and 500V D.C.; 0.01, 1, 10 and 100 mA D.C.; and 1, 10, 100, 1K, 10K and 100K ohms. Accessories are available for event marking; six-input on shared time basis; A.C. recording up to 300V R.M.S.; centre zero chart; and others. The VOM-6 and VOM-7 are also available and have respectively 2.5 mV and 500 microvolt full scale spans.

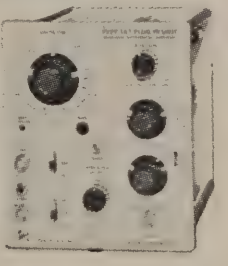


TEKTRONIX TYPE 564 STORAGE OSCILLOSCOPE—The Type 564 is a low-priced version of the Type 549 described above but accepts 2—series and 3—series plug-in units. The time-base is provided as a separate plug-in.

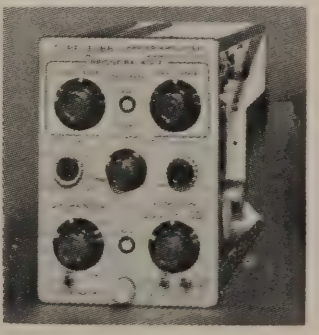
TEKTRONIX TYPE 1A7 DIFFERENTIAL UNIT

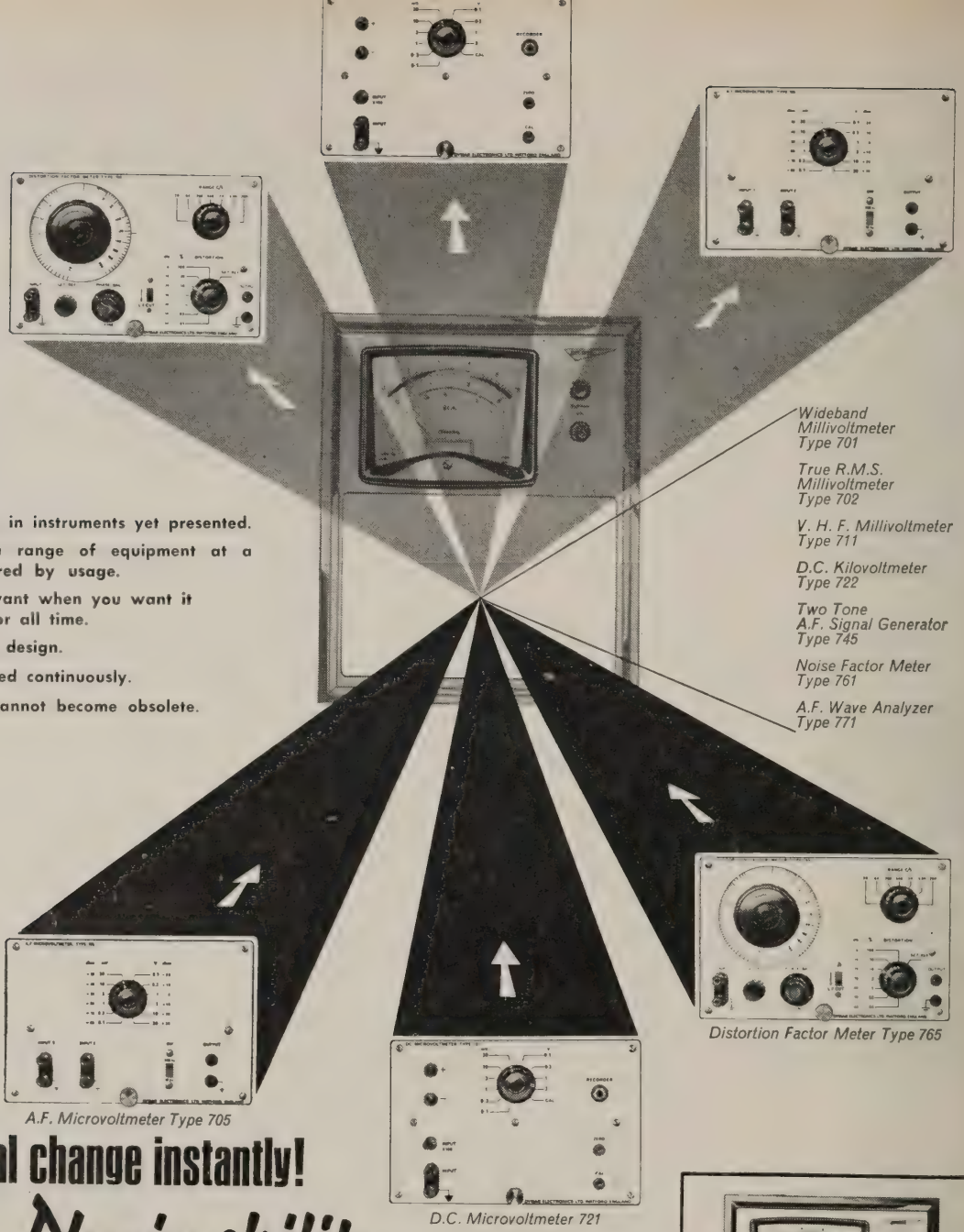
DC TO 500 KHz Selectable Bandwidth.—10 V/cm to 10 μV/cm deflection factor Low DC drift, low noise.

This general-purpose plug-in unit can be used with any Tektronix 530, 540, 550, or 580-Series Oscilloscope. Used with Type 127, 132 or 133 Power Supply, the 1A7 can drive recording equipment, X-Y plotters, oscilloscopes or other indicators. Capable of differential measurements with simultaneous DC offset, the 1A7 allows observation of very small differential signals which may have a considerable difference in DC potential. Common-mode rejection is 50,000:1.



TEKTRONIX CARRIER AMPLIFIER—The Type 3C66 with suitable transducer measures mechanical quantities that can be converted to a change in resistance, capacitance, or inductance. This unit may be used in the Type 651A, Type 564, Type 565 and Type 567 Oscilloscope. However, in the Type 567 and RM567, the measurements will not be permitted in digital form. Used with the Type 129 Power Supply, the Type 3C66 can drive recorders, X-Y plotters, oscilloscopes, or other indicators.





Wideband Millivoltmeter Type 701

True R.M.S. Millivoltmeter Type 702

V. H. F. Millivoltmeter Type 711

D.C. Kilovoltmeter Type 722

Two Tone A.F. Signal Generator Type 745

Noise Factor Meter Type 761

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The largest range of plug in instruments yet presented.

Ideal for building up a range of equipment at a reasonable cost as required by usage.

You buy what you want when you want it then you have it for all time.

Fine construction and design.

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Distortion Factor Meter Type 765

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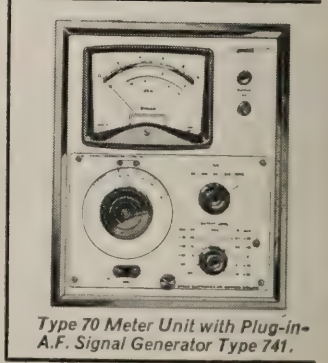
total functional change instantly!

that's *Pluginability*

—that's the Dymar System—a system of plug-in instruments offering flexibility and considerable capital saving. The basis of the system is the Type 70 Meter Unit which will accept any of a series of plug-ins. A change of function occurs with each combination because it produces *a different instrument.* Just release the retaining rod, withdraw the plug-in and insert another. It's as simple as that and 'Pluginability' sums it up in one word.



Type 70 Meter Unit with Plug-in A.F. Signal Generator Type 741.

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Thoughts on a Conference

Right now it should be said that it is realised that as something under ten per cent of our readership will be attending the National Electronics Conference this August, the other 90 per cent may well already be tired of, and uninterested in, our efforts at publicising this Conference.

However, at the Conference committees, this journal has had its representatives to both report on and work towards this first national event. What has come to light has been something of an eye-opener. From the outset it was realised that the level should be such that a technician or serviceman would share in discussions, meetings and on hearing the actual papers he would become more acquainted with the scope of electronics in this country.

Two sections in particular, Education and Medical Electronics, have been slanted towards the end of general technical appeal. The first surprise, then, was the poor response from the largest body of electronic workers — technicians and servicemen. In over 300 enrolments less than 30 are from this section of the industry.

In converse, the other surprise is the large number enrolled from fringe sources — people we certainly would never have thought of putting on a mailing list. It is this group that emphasises the spread of electronics into the non "radio" field.

The most pleasant thing, however was the large number of papers received, over 80. Just as important is the fact that over 40 are from non-government sources. This disproves the oft said statement that government is the only large user or designer of electronic equipment in New Zealand.

Whilst the Conference response has far exceeded expectations of the planners the extremely pleasing thought is that the greatest response has come from the quarter that it was thought would be the toughest to crack — the professional users and designer. The industry section most needing the cohesion a Conference can provide — technicians and servicemen having no active society or association of their own at present — were the least responsive.

It is obvious that the lack of cohesion and of a spirit of corporate togetherness is depriving this, the largest, group in the electronics industry, of worthwhile and useful experience.

If one is satisfied to service television sets or industrial controls until pension day comes at 65, then Conferences and societies can be forgotten but even domestic appliances improve and employ new techniques or components, so to stay in the game new knowledge must be acquired from time to time.

Tentative discussions are already under way for the second National Electronics Conference two or three years away. In the intervening period the technician group should perhaps employ the time in organising themselves into a society such as the British body — the Society of Electronic and Radio Technicians — with the avowed object of promoting knowledge and extending interest in their side of the industry. Or else to a similar end they could form a definite section within the already existing New Zealand Electronics Institute.

The technician today is the largest force in the electronics industry and yet once he has qualified he has no voice in the industry (apart from his union — and then only on wages and work conditions). A strong technician group could keep its members up to date on service techniques, new methods and equipment, instrumentation. In the field of technician education such a society could advise Government on the needs for apprentice training and post-first certificate courses.

Certainly, this writer when joining the Conference committee did not realise that out of it would emerge the need for an organisation catering for technicians because they hadn't come — what would have been so much better would be for this first Conference to have been the foundation for closer co-operation and contact within this section of the industry.

A lot can be achieved in two years so it is hoped that the next National Electronics Conference will see a strong contingent to present the viewpoints and problems of the technician. It is naturally hoped that employers and department heads will be able to make it possible for technicians and service personnel to attend.

C.W.S.

Current Investigations of Sub Ionospheric Propagation of VLF Radio Signals

G. J. BURTT
Physics and Engineering Laboratory
Department of Scientific and Industrial Research
Lower Hutt, New Zealand

INTRODUCTION

The widespread and still growing use of very low frequency radio for various purposes has stimulated a growth in research on the propagation of radio signals in this band. There are two reasons for this. There is the purely practical reason of solving various problems that have arisen or are expected to arise in the operational use of this band. The other is that the existence of powerful radiations from a number of VLF transmitters provides an opportunity for investigations on the lower regions of the ionosphere, and also on the exosphere, the region beyond the upper ionosphere. In this paper we are concerned with propagation in the lower ionosphere and below.

VLF is at present used for four distinct purposes, for long range communication, for the propagation of standard frequencies and time signals, and for long range position fixing navigation systems. It can also be used for the detection of distant nuclear explosions. For all these purposes, the comparatively high reliability and stability of the signal level of VLF at even the longest ranges, at all times of day and in almost any ionospheric condition normal or stormy, is a distinct advantage. The very high stability of the phase of signals received at medium and long distances is the essential quality that makes VLF so suitable for standard frequency dissemination and for long range position fixing navigational systems.

Most of the VLF transmitters in use today are frequency stablised. That is to say the frequency of the carrier is controlled to close limits using a very good crystal oscillator which is either servo-controlled by, or monitored against, an atomic frequency standard. Elaborate precautions are taken to prevent short term phase variations due to capacity changes in the huge aerial arrays in high wind or when the ground conductivity changes. In almost all cases the frequency as transmitted is guaranteed in accuracy to one or two parts in 10^{10}, averaged over a period of 24 hours.

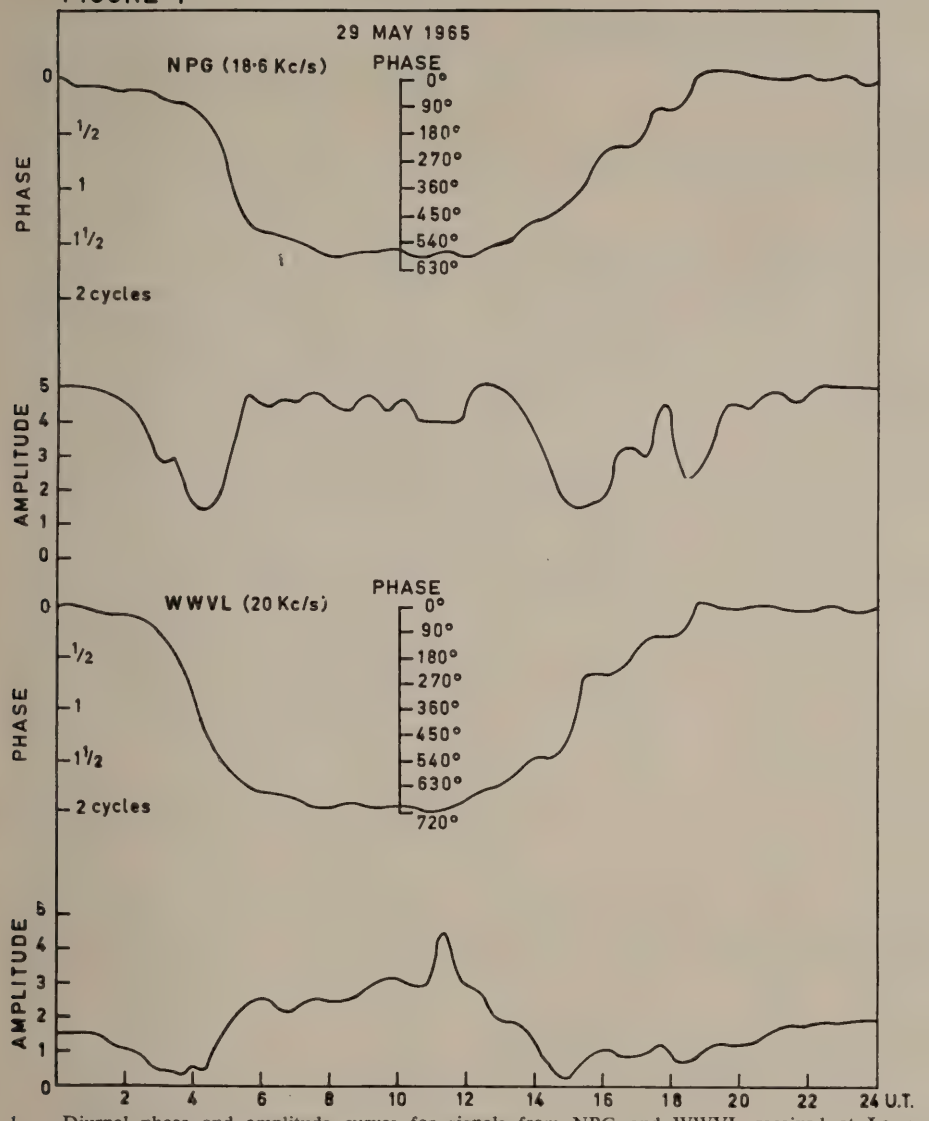
The obvious parameters that can be measured are the field strength, the phase stability, and the angles of arrival of the wavefront at the receiving site. The research that is being carried out at the present time is very largely based on observations of the phase and signal level variations. The equipment necessary is comparatively simple and inexpensive — the biggest item being a very stable oscillator for use as a reference standard.

The simplest method of recording the data is to produce a beat frequency trace. This method was introduced some years ago, and is still regarded as having many advantages over more sophisticated methods of recording which are now regarded as standard practice. The radio signal is received using a simple aerial — a moderately sized frame loop aerial is preferable. (A 6 ft square frame aerial with about six turns on it is typical). The receiver consists of a radio frequency amplifier followed by a detector in which the incoming radio signal is mixed with a signal of almost the same nominal frequency, but derived from the local reference oscillator.

The resultant output is a beat frequency, the difference between the incoming radio frequency and the signal derived from the reference. It is then necessary to pass the output through an R.C. network which acts as a narrow band filter. Working in New Zealand where the signals from many VLF stations are only just above or are right down in the noise, it is necessary for the filter bandwidth to be restricted to something of the order of 0.02 - 0.03 of c./s. Only thus can an interpretable output be recorded. The recorder can be an inked paper recording milliammeter driven by clockwork or a synchronous electric motor.

If the receiver amplifier is reasonably linear the amplitude of the beats is a measure of the incoming signal amplitude. If one assumes the frequency of the reference to be invariant, the variations in beat frequency are a measure of the phase variations of the incoming signal. By taking a mean for the beat interval over, say, a 24 hour period, one can calculate the cumulative differences in beat interval, and plotted against time they will give a phase variation curve of the incoming signal.

FIGURE 1



1. Diurnal phase and amplitude curves for signals from NPG and WWVL received at Lower Hutt on 29 May 1965.

Equipment has now been developed and is commercially available in which the reference signal frequency has little or no offset from the mean frequency of the received radio signal, and the phase difference between the two is converted to a voltage and plotted directly against time. This equipment normally also has a signal level output which is separately recorded.

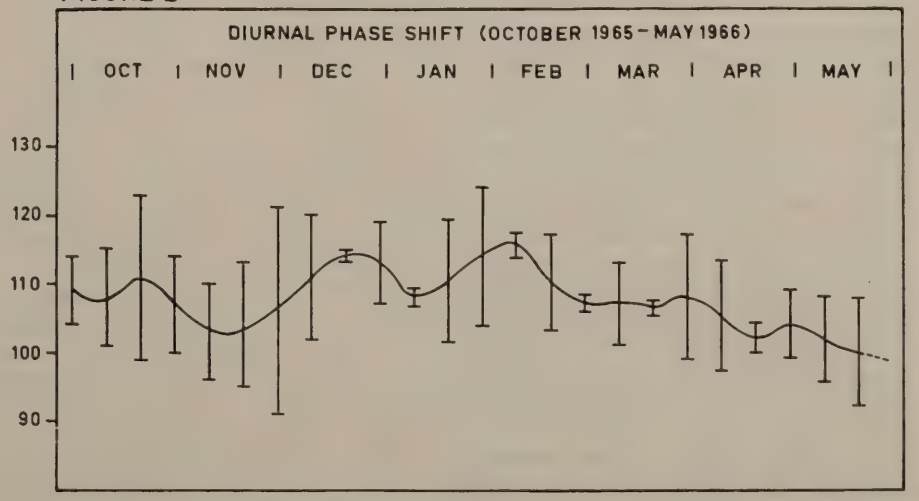
DIURNAL AND SEASONAL PHASE AND AMPLITUDE VARIATIONS

In a previous article[1], I referred to the typical diurnal phase variation curve for long distance reception, with its stable periods when the path is wholly in sunlight or darkness, and the transition periods — a phase lag when the sunset line is advancing over the path and a phase advance during the sunrise traverse. In practice, the observed diurnal variations usually depart considerably from the idealised curve. Some of the deviations can be readily explained in terms of the normal or sometimes abnormal changes in conditions in the earth-ionosphere waveguide region, whereas some are as yet not explained, or can only be explained in terms of as yet unproved theory.

In Figure 1 are shown actual phase curves for stations NPG, Seattle and WWVL, Boulder, as received at the Physics and Engineering Laboratory, Lower Hutt. It is noticeable that the depth of the trapezoid — that is the difference between the mean daytime and night-time phase values, is significantly different for the two stations. This diurnal phase shift is a function of the length of the signal path and also of the radio frequency. The higher the frequency the greater the diurnal shift. NPG and WWVL are at approximately the same range from Lower Hutt — NPG on 18.6 kc/s being 11,800 km and WWVL on 20 kc/s, 12,300 km distant.

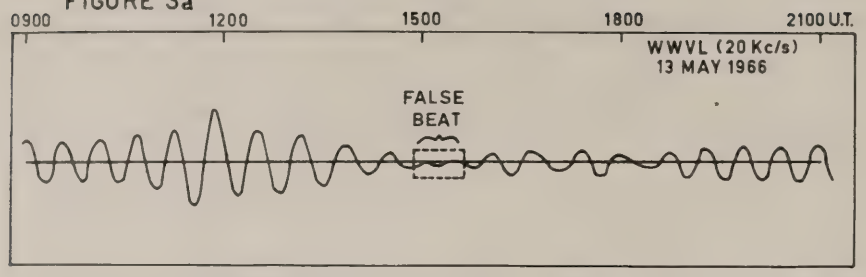
A continuous series of observations on WWVL at Lower Hutt shows considerable variations from day to day in the value of the shift. A plot of diurnal shift values over a long period shows some seasonal effect (Fig. 2). Large day to day variations might be expected to be related to disturbed ionosphere conditions, whereas the apparent

FIGURE 2



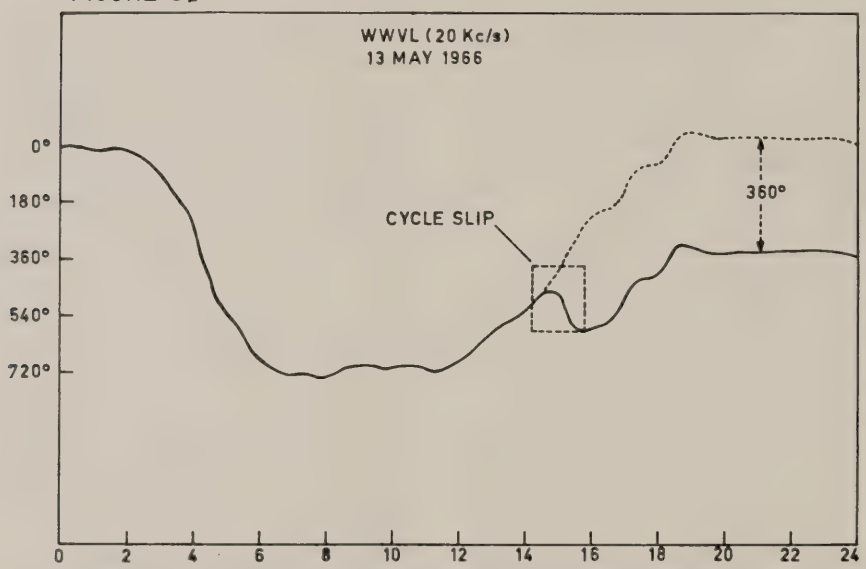
2. Diurnal phase shift of WWVL signals as received at Lower Hutt. The solid curve shows the mean drawn on a plot of daily values. The vertical lines give a measure of the day-to-day scatter throughout the period of observation.

FIGURE 3a



3. (a) Part of a beat frequency record of WWVL signals received at Lower Hutt (13 May 1966) showing "false beat" producing "cycle slipping."

FIGURE 3b



(b) Phase plot of WWVL for (13 May 1966) showing false phase shift during sunrise. Dotted curve shows correct phase shift after correcting for "cycle slip."

seasonal effects should be related to changing solar zenith angle and the consequent seasonal change in daytime ionisation densities in the lower ionosphere. Both these matters are being examined at the present time.

The mean slopes of the phase curves (Fig. 1) occuring at the transition times from night to day and day to night agree in most cases with the expected rate of phase change as the sunrise or sunset line traverses the signal path. However, it is the considerable deviations from the straightforward phase advance or retardation during these periods, which can occur in certain circumstances, that are the subject of most interest at the present time.

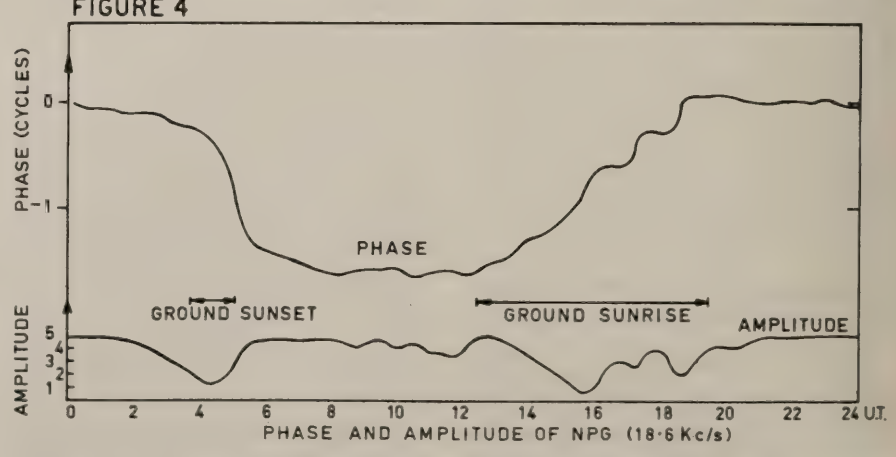
In my earlier article I referred to work by Thompson[2] in Australia and the author[3] in New Zealand on observations of station NBA (Panama) on 18 kc/s. The observations showed that the sunrise phase advance did not normally take place as a smooth rise, but was in steps, and that on occasions during this phase advance there could occur a quite sudden retardation of one or possibly two whole 360° cycles.

Since then, further observations on other stations have shown this phenomenon of "cycle slipping". Gerard[4] working at Lower Hutt has observed cycle slipping on the signal from GBR (Rugby) on 16 kc/s, at certain times of the year, and Spackman, also working on GBR in Auckland has records of this. McNeill at Lower Hutt has observed it on NPG on 18.6 kc/s at times, and on WWVL on 20 kc/s it has occurred consistently every day for a period of more than a year (Fig. 3). A recent paper by Carpenter[5] shows evidence of cycle gains at sunset over a fairly short path down the west coast of America from the NPG transmitter to Tracy, near San Francisco. Kaiser[7] has also found examples of cycle gains at sunset on the NBA — Lower Hutt path during the southern hemisphere summer.

The sunrise cycle losses observed on NBA were attributed by the author to interference between the signals arriving by the short and the long great circle paths. This is theoretically possible since Thompson established that for long periods of the day the long path signal is the stronger and that at the critical sunrise period the signals are comparable in strength. During the short path sunrise period, the phase of the long path would be retarding, and it has been shown in both papers [2 & 3] how a combination of two signals with counter rotating phase vectors could produce cycle gains or losses. Thompson, however, was able to separate the long and short path signals and showed evidence of a cycle loss on the short path signal. This, he suggested, was due to interference between signals travel-

Continued on page 33

FIGURE 4



4. Phase plot showing stepped phase shifts and amplitude variations which can be explained by multi-mode interference.

Field Effect Transistors

One of the major disadvantages of the conventional junction transistor is its inherently low input impedance. Careful circuit design is necessary to overcome this and circuits have been produced which provide input impedances of the order of megohms. These circuits are usually fairly complex and frequently require several transistors.

The field effect transistor (F.E.T.) offers considerable advantages over the conventional transistor in that it is essentially a voltage controlled device with an input resistance of the order of hundreds of megohms at room temperature. In addition the F.E.T. has no offset voltage, a low noise figure and a high power gain (approaching that of a valve).

This application note describes the F.E.T. and its characteristics. In a further article some applications of the F.E.T. will be described.

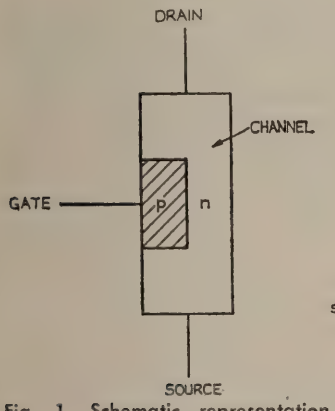


Fig. 1. Schematic representation

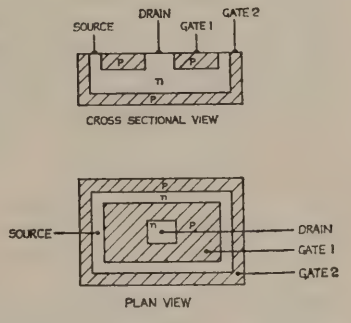


Fig. 2. Commonly used structure

General Description

A schematic representation of a field effect transistor is shown in Fig. 1. In its simplest form the F.E.T. is a three terminal device comprising a slice of semiconductor material with a p-n junction formed along one side. The region between the source and drain connections is called the 'channel'. The gate connection is taken from the p-type region of the junction. The semiconductor material is silicon.

For many purposes it is useful to regard the source, gate and drain as being equivalent to the emitter, base and collector of a conventional transistor. The gate-channel junction is normally operated as a reverse biased diode and consequently the gate input impedance is very high (10^{-9} amps in terms of leakage current). Current flows in the channel from source to drain and is carried predominantly by charges of one type (in the case of the n-channel device the charge carriers are electrons). This has led to the name 'unipolar' F.E.T. in order to further distinguish these devices from junction transistors which are in this sense 'bipolar' devices.

When a reverse voltage is applied to the gate-channel junction its depletion layer is extended and the effective channel width is reduced resulting in a decrease of channel conductance. This change in conductance is an 'effect' of the transverse electric 'field' applied to the junction and gives rise to the name 'field effect' transistor. In practice the physical form of the F.E.T. is not the simple one shown in Fig. 1 and a commonly used structure is shown in Fig. 2.

Oxide masked diffusion and epitaxial techniques are used to form the channel and gate 1 regions on the p-type substrate which forms gate 2.

The two gate regions are usually connected together in the external circuit although they may be used separately (as discussed later).

Operation

It has been indicated briefly that the channel conductance is an inverse function of the gate-to-channel voltage. As this voltage is made more negative, the depletion layer extends further into the channel region. If the initial channel width is sufficiently small the depletion layer will eventually extend far enough to 'pinch off' the channel and reduce the conductance virtually to zero. The gate to source voltage necessary to do this (with the drain to source voltage (V^{DS}) at zero) is known as the pinch off voltage (V^{P}). For a ZFT12 F.E.T. V^{P} is typically 1.5V and for a ZFT14, is 5V. Fig. 3 shows the effect of increasing the gate-source reverse voltage on channel width.

Now consider what happens when the drain voltage is increased with the source and gate grounded. When a positive voltage is applied to the drain, an electron current flows through the channel from source to drain. As a result of the voltage drop along the

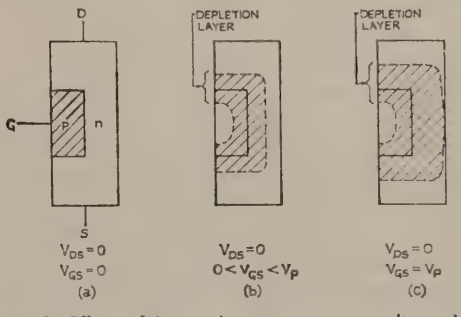


Fig. 3. Effect of increasing gate-source voltage V_{GS}

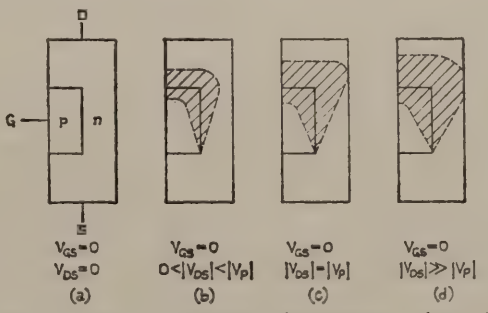


Fig. 4. Effect of increasing drain-source voltage V_{DS}

Based on application note no. 22, published by Ferranti Ltd., Electronics Dept. From "S.E.R.T. Journal," Vol. 1, Nos. 2, 3.

resistance of the channel, the reverse bias on the gate-channel junction is not constant along the channel length. This bias is greatest near the drain and decreases steadily to its lowest value near the source, with the result that the channel takes on a wedge shape, as shown in Fig. 4 (b). As the drain voltage is further increased, the channel width is reduced until, when the drain voltage reaches V^P, the channel becomes very constricted over a small region. Further increase in drain voltage results in no further increase in drain current, that it, saturation of the drain current occurs. The process is shown in Fig. 4.

When voltages are applied to both gate and drain simultaneously, their effect is additive and the resulting reverse bias on the gate is the sum of the separate voltages. Drain current saturation now occurs when this sum voltage reaches V^P. Throughout the above discussion stress has been laid on the gate-channel junction being reverse biased. In fact it is quite allowable to use the F.E.T. with a small positive voltage (0.25V–0.5V) between gate and channel provided that the gate-channel diode is never turned on.

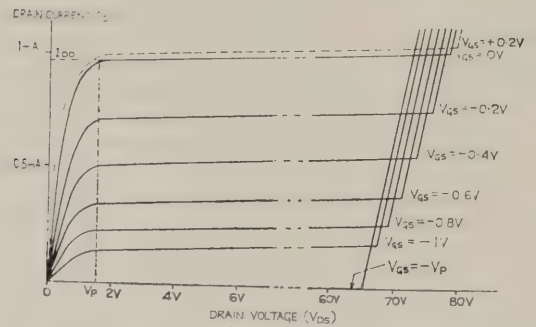


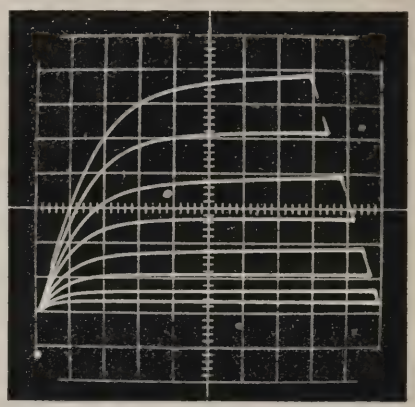
Fig. 5. Drain current/Drain voltage characteristic

Summarising, Fig. 5 shows the drain current/drain voltage static characteristics for a typical F.E.T. type ZFT12. At low drain currents the effect of voltage drop along the resistance of the channel is negligible and the F.E.T. behaves as an almost linear voltage controlled variable resistance.

However, as drain voltage is increased and the drain current rises, the depletion layer widens and eventually the drain current saturates. When this has occurred increase in drain voltage produces scarcely any increase in current until the drain-gate breakdown voltage is reached. With the gate-source voltage at zero the drain current becomes saturated at a drain voltage of the magnitude of V^P. This current is called the drain saturation current I^{DO} (I^{DO} is typically 1mA for a ZFT12 and 6mA for a ZFT14.) When the gate is reverse biased, saturation occurs at a lower drain voltage, as explained previously, and the drain current saturates at a lower level.

The characteristics of the ZFT14 are similar in general nature to the above, but having I^{DO} typically 6mA and pinch off voltage 5V.

A measure of the effect of gate voltage on drain current is given by the mutual conductance g^m. As shown in Fig. 6, the unequal spacing of the characteristics for equal increments in gate voltage illustrates the dependence of g^m of gate voltage. The maximum value of g^m occurs near I^{DO} so that for small signal operation, optimum gain is obtained by operating the F.E.T. near the zero gate bias point. For a ZFT12 device g^m is typically 1.5mA/V and for a ZFT14 is 3mA/V measured with $V^{DS} = 20V$.



Vertical 0·2mA per division
Horizontal 0·5V per division
Running Parameter—0·2V per step

Fig. 6. ZFT12 Characteristic displayed on a curve trace

Small Signal Equivalent Circuit

The small signal equivalent circuit of the F.E.T. is shown below in Fig. 7.

R^{in} represents the reverse bias resistance of the gate-channel junction and is the lumped equivalent of the resistances of the gate-drain and gate-source diodes. In a similar way C^{in} represents the combination of gate-drain and gate-source capacitances, C^{GD} and C^{GS} respectively. R^o represents the output resistance of the F.E.T. and is the slope resistance of the I^{DO} portion of the static characteristics.

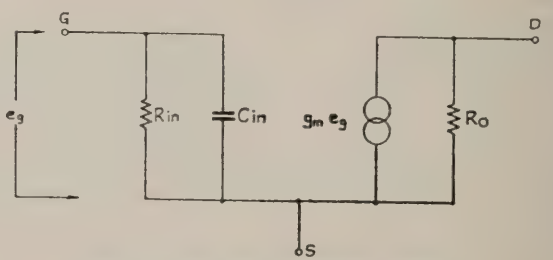


Fig. 7. Small signal equivalent circuit

R^{in} and C^{in} are both measured with the source and drain grounded and the two gates joined.

Typical values at 25°C for a ZFT12 and ZFT14 are R^{in}—1000MΩ, C^{in}—30pF, R^o—250kΩ.

It can be seen at once that at frequencies greater than a few cycles per second the input impedance is largely determined by the input capacitance. However, if the F.E.T. is operated with gate 2 grounded the input capacitance at gate 1 falls to about 10pF. This improvement is realised at the expense of a reduction in g^m. Due to the dependence of gate capacitance on reverse bias, when the F.E.T. is operated in the constant current region, C^{GD} is smaller than C^{GS}. This is a result of the larger reverse bias at the drain end of the gate-channel junction and the ratio C^{GD}:C^{GS} is typically 1:6.

Temperature Effects

There are two types of temperature effect in the F.E.T. These are the variation of gate leakage current and drain saturation current. I^{DO}.

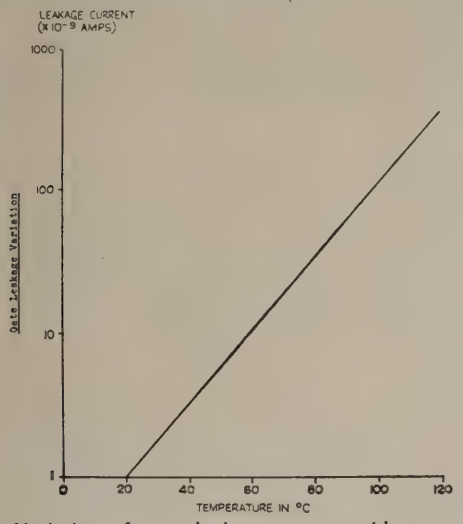


Fig. 8. Variation of gate leakage current with temperature

The above figure is a typical graph showing the variation of gate leakage current with temperature for ZFT12 and ZFT14 transistors. The graph shows the usual positive logarithmic function associated with the reverse leakage of a junction diode. The junction area of the F.E.T. is significantly larger than that of a typical small silicon diode so that the magnitude of the gate leakage current is larger.

The drain saturation current I^{DO} is directly proportional to the resistivity of the channel material, which in turn is inversely proportional to the carrier mobility. Consequently I^{DO} is temperature dependent as shown in Fig. 9.

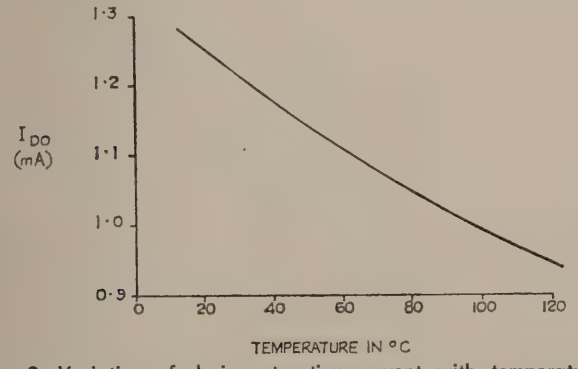


Fig. 9. Variation of drain saturation current with temperature

Using the F.E.T. in high input impedance Amplifiers

In the design of high input impedance stages, the mode of biasing must be carefully considered. For stable operation it is necessary to provide a direct current path from gate to source and as a result the effect of gate leakage current and its variation with temperature must be taken into account.

Since the maximum value of g^m occurs near I^{DO}, optimum gain for small signal operation is obtained by operating the F.E.T. at or near the zero gate bias point so that bias voltages of the order of tenths of a volt are common.

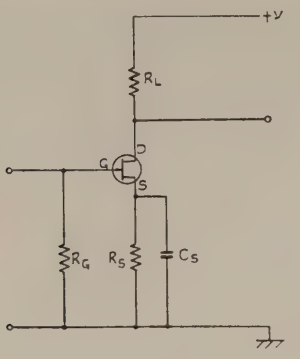


Fig. 10. Provision of bias

One method of providing bias is shown in Fig. 10 above. In addition to providing the bias, the source resistor R^S provides d.c. negative feedback. For constant gate bias, the drain current (and g^m) decreases with increasing temperature. When this occurs the resultant change in source current causes a change in gate-to-source-voltage-which opposes the initial change in drain current.

If an input impedance of say, 10MΩ, is required then the value of R^G must be at least 10MΩ itself as it shunts the input circuit. With this particular value of R^G the gate bias could vary by as much as a volt over the range 25°C–100°C with a resultant change in drain current and g^m. If this variation is intolerable in a given application then it is necessary to restrict the temperature range or reduce R^G and be satisfied with a lower input impedance.

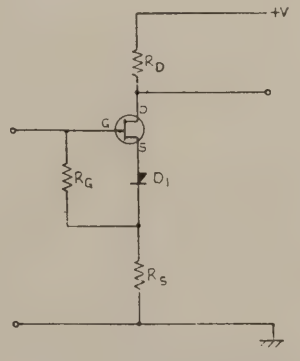


Fig. 11. Bootstrap connection

The voltage amplication of the circuit is given:

$$M = \frac{g^m R^L}{1 + \frac{R^L}{R^O}} = g^m R^L$$

Fig. 11 shows an alternative method of biasing where the decoupled resistor R_1 provides the bias and d.c. negative feedback. The resistor R_2 in addition, provides signal negative feedback and increases the input impedance to the stage (at a cost of reduced gain). By this means some improvement over the circuit of Fig. 10 is to be expected. For a given input impedance R^G may be made smaller than before with subsequent better stability at high temperatures.

This type of connection, often used to provide a high input impedance, is usually known as 'bootstrapping'.

In Fig. 12 diode D_1 serves to bootstrap the gate

resistor R^G and to provide gate bias. The diode provides full decoupling at the lowest frequencies and is smaller and cheaper than a resistor and decoupling capacitor so that this circuit is probably the most convenient of the three described.

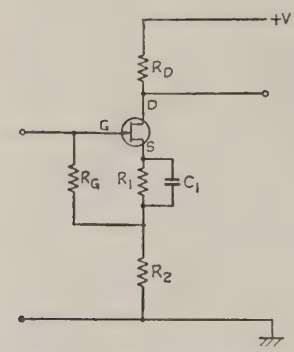


Fig. 12. Use of diode to provide bias

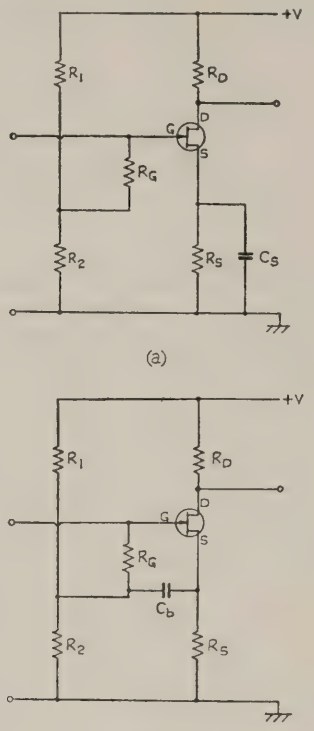


Fig. 13. Potential divider source resistor bias with and without boot strap.

Fig. 13 (a) illustrates potential divider, source resistor biasing where the bias voltage is dependent on the values of R_1, R_2 and R^S. The resistor R^G is included to reduce the shunting effect of R_1 and R_2 on the input. The input resistance is substantially the value of R^G and the previous remarks concerning gate leakage apply equally here. For very high input impedance stages for operation over a small range of temperatures R^G may be as high as 10MΩ or 20MΩ.

Fig. 13 (b) shows another version of the same circuit when 'bootstrapping' is provided by the capacitor C^b. By this means a higher input impedance can be achieved than in the circuit of Fig. 13 (a).

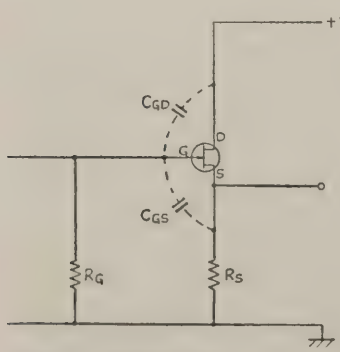


Fig. 14. Source follower circuit

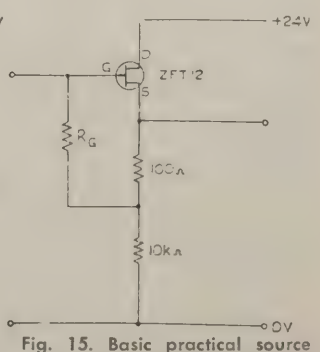


Fig. 15. Basic practical source follower

Obtaining Maximum Input Impedance

It has already been mentioned that above a few cycles per second the input impedance of the F.E.T. is determined almost wholly by the input capacitance. When the F.E.T. is working in the constant drain current region the gate-drain capacitance is typically 10pF and the gate-source capacitance 20pF. It is thus important to keep input capacitance to a minimum and the 'source follower' circuit is commonly used for this reason.

The basic 'source follower' is shown in Fig. 14 and includes the F.E.T. gate capacitances C^{GD}, C^{GS}. The source resistor R^S provides negative feedback which both improves the circuit stability and reduces the effect of the gate to source capacitance C^{GS}.

The gain of the stage is given by

$$M = \frac{g^m R^S}{1 + g^m R^S}$$

and C^{GS} is effectively reduced to an equivalent value

$$C'^{GS} = C^{GS} (1 - M)$$

As M approaches unity C'^{GS}approaches zero.

By application of similar feedback to the drain the effect of C^{GD} can also be significantly reduced.

Practical Circuit

In conclusion some practical circuits will now be described which use the technique outlined above. All these circuits are based on the source follower and have gains slightly less than unity. In each case the input impedance is quoted in terms of input resistance R^{in} and input capacitance C^{in}.

With $R^G = 56k\Omega$	$R^G = 1M\Omega$	$R^G = 10M\Omega$
$R^{in} = 1M\Omega$	$R^{in} = 15M\Omega$	$R^{in} = 150M\Omega$
$C^{in} = 5.6pF$	$C^{in} = 5.5pF$	$C^{in} = 6pF$

The values of R^{in} and C^{in} for the particular values of R^G quoted, indicate the range of input impedances which may be obtained. C^{in} remains essentially constant at 5–6pF while R^{in} increases with increase of R^G.

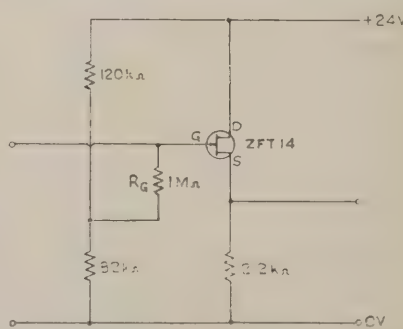


Fig. 16. Source follower with potential divider biasing

Fig. 16 shows the source follower with potential divider biasing. R^{in} and C^{in} are quoted for one value of R^G only. R^{in} is essentially equal to the value of R^G and a range of input impedances is obtainable as before.

With $R^G = 1M\Omega$

$R^{in} = 1M\Omega$
$C^{in} = 7.9pF$

The circuit shown in Fig. 17 is the bootstrap version of the previous circuit in Fig 16. The same value of R^G

Continued on page 33

A paper from the NEW ZEALAND ELECTRONICS CONFERENCE

Frequency Engineering For VHF Mobile Services

R. Cassey, B.Sc., MNZIE, MIERE, AMIEE, Divisional Engineer, NZPO

The paper describes the various types of mobile service and the international and national considerations involved in the allocation of frequency bands for their use. This is followed by an outline of the technical and other factors which have to be considered when planning the assignment of the frequencies in these bands.

1. Introduction

There are three types of mobile service. These are the maritime mobile service which is comprised of coast and ship stations; the land mobile service comprised of base and land mobile stations; and the aeronautical service comprised of aeronautical and aircraft stations. It is important to note that coast, base, and aeronautical stations are located at fixed geographical positions and are referred to collectively as "land stations".*

2. Band Allocations

International cooperation is necessary if mutual interference between stations is to be avoided, and to this end radio frequency usage has been included in the deliberations of the International Telecommunications Union, (ITU), since its first radio conference at Berlin in 1906. At that time only the lower frequency bands were considered. Higher frequency bands were dealt with later as they came into use.

The first allocations for the whole of the VHF band (30-300 Mc/s) were made at Atlantic City in 1947. They were modified and extended at Geneva in 1959 and 1963.

As a signatory to the ITU Convention, New Zealand follows these band allocations. The bands available for the mobile services in New Zealand are broadly as shown in Table I. It will be noted that most of the bands are shared by several services. Wherever possible, one of the services is given the exclusive use of a band, or portion of a band. This is treated as a national matter and is dealt with by the Frequency Advisory Sub-Committee comprising representatives of certain Government Departments, including the Post Office, which, inter alia, makes submissions relating to all users who are not otherwise represented. The Sub-Committee is responsible for advising the Postmaster General about band allocations.

3. Channelling Considerations

The major task in the allotting of the channels within each band is the determination of the significant parameters on which this channelling must be based. Some of these will now be considered.

3.1 Bandwidth

The ITU defines three different kinds of bandwidth. If we take measurements on an emission and note the two frequencies beyond which 0.5% of the total mean power is radiated, then these two frequencies define the limits of the **occupied bandwidth.** The minimum occupied bandwidth which will enable the required information to be transmitted is the **necessary bandwidth.**

The necessary bandwidth in itself is not sufficient since the carrier frequency may be anywhere within the permitted frequency tolerance for the kind of station concerned. Hence the **assigned frequency band** comprises the necessary bandwidth plus twice the frequency tolerance.

The International Radio Regulations provide appropriate formulae for the calculation of the necessary bandwidth. In commercial telephony, the figure is 6 kc/s for amplitude modulation and 36 kc/s for frequency modulation. The Regulations also specify the frequency tolerances which are expected to be met by the signatory countries.

3.2 Receiver Characteristics

In practice, the closeness of the channel spacing depends also on the stability of the receiver and its bandpass characteristics. No inter-

TABLE I
INTERNATIONAL BAND ALLOCATIONS FOR NEW ZEALAND

30 - 44 Mc/s	Fixed and Mobile
44 - 51	Fixed, Mobile and Broadcasting
51 - 53	Fixed Mobile and Amateur
53 - 54	Fixed and Mobile
54 - 68	Fixed Mobile and Broadcasting
68 - 70	Fixed, Mobile and Aeronav
70 - 78	Fixed and Mobile
78 - 80	Fixed Mobile and Aeronav
80 - 83	Fixed and Mobile
83 - 87	Fixed, Mobile and Radionav
87 - 100	Fixed, Mobile, Broadcasting and Radionav
88 - 100	Fixed, Mobile and Broadcasting
100 - 108	Fixed and Mobile
108 - 118	Aeronav
118 - 132	Aero Mobile (R)
132 - 136	Aero Mobile (OR)
136 - 137	Fixed and Mobile & Space
137 - 138	Space
138 - 144	Aero Mobile (OR)
144 - 148	Amateur
148 - 156	Aero Mobile (OR)
156 - 170	Fixed and Mobile
170 - 200	Fixed, Mobile and Broadcasting
200 - 216	Fixed, Mobile, Broadcasting & Aeronav
216 - 225	Aeronav
225 - 235	Fixed, Mobile and Aeronav
235 - 300	Fixed and Mobile

Note: Certain individual special frequency assignments are not shown above, e.g., 75 Mc/s for aerobeacons, 40 Mc/s for Space Research, 150 Mc/s for Radionavigation-satellite, etc.

* It is incorrect to refer to them as "fixed stations" since that term is reserved for stations providing point-to-point communications.

TABLE II
CHANNELLING IN THE BAND 156-174 MC/S FOR THE MARITIME MOBILE SERVICE

Channel	Transmitting Frequencies (Mc/s)		
	Ship Stations	Coast Stations	
1	156.05	160.65	
2	156.10	160.70	
3	156.15	160.75	
4	156.20	160.80	
5	156.25	160.85	
6	156.30		
7	156.35	160.95	
8	156.40		
9	156.45	156.45	
10	156.50		
11	156.55	156.55	
12	156.60	156.60	
13	156.65	156.65	
14	156.70	156.70	
15	Guard Band		
16	156.80	156.80	CALLING AND SAFETY
17	Guard Band		
18	156.90	161.50	
19	156.95	161.55	
20	157.00	161.60	
21	157.05	156.05 or 161.65	
22	157.10	161.70	
23	157.15	156.15 or 161.75	
24	157.20	161.80	
25	157.25	161.85	
26	157.30	161.90	
27	157.35	161.95	
28	157.40	162.00	

national limits are specified for these but the International Radio Consultative Committee (CCIR) provides some statistics. Information of the latest developments by the major communications companies is also available.

In conjunction with the receiver characteristics, it is necessary to consider the effects of the power output of the transmitters. The lower the power, the greater the number of channels which can be accommodated.

3.3 International Coordination

In the maritime and aeronautical services, ships and aircraft may be required to communicate with stations in other countries. Hence the channelling of their bands is determined by international agreement.

For ships operating in the 156 Mc/s band, agreement was not reached on technical characteristics until the CCIR meeting at Warsaw in 1956. This was followed by a frequency plan at the ITU Geneva Meeting in 1959, as shown in Table II below. This plan is expected to be reviewed in 1967 as it suffers from a number of defects, the major ones being —

(a) the loss of channels 15 and 17 because of the danger of transmissions on these channels causing loss of reception of distress messages on channel 16, as a result of "capture effect".
(b) the small number of channels which can be accommodated in the band as a resutl of the use of FM with 50 kc/s channelling.
(c) the impracticability of using several channels at a common site because of intermodulation effects as referred to in section 3.4 below.

In the aeronautical service, the plans of the International Civil Aviation Organisation (ICAO) are in use. The plan for the 118-132 Mc/s band for example is based on the use of amplitude modulation and 50 kc/s channelling. It suffers from some of the same defects as the maritime plan.

3.4 Co-siting and Intermodulation Aspects

Whenever two signals are applied to a non-linear device, intermodulation occurs and results in the production of additional frequencies. If the two signals are 100 kc/s apart, then these intermodulation products occur at every 100 kc/s above and below the original frequencies. If the band has been channelled on a 100 kc/s basis, they fall precisely on all of the other channels. Several things may be done to minimise this effect —

(a) The channels may be selected for each station so as to keep the problem to a minimum, but this is practicable only if a limited number of channels is required and there is a large number to choose from.
(b) Two-frequency operation may be used and the receive frequencies so spaced that the intermodulation products fall in the spaces between the receiving channels.
(c) The rectifying sources may be made ineffective by careful jointing where metallic connection is necessary; or conversely by careful insulation. Bonding across poor metallic contacts is not generally effective at VHF because of the likelihood of resonant loops being formed.
(d) The fitting of filters, and the separation of transmitting and receiving sites may be adopted so as to prevent unwanted signals being applied from the aerial system to the input circuit of the receiver, or the output circuit of the transmitters since both of these circuits may act as rectifier units.

3.5 Channel Interleaving and Splitting

When a particular channelling plan has been prepared, a second or third plan having its channels interleaved with those of the original, may be introduced. These interleaved plans may be used in the areas between those in which the first one is in use. The distance between the stations reduces the likelihood of interference and this interleaving effectively increases the number of channels.

As the transmitter and receiver stabilities improve and better filters become available, the possibility arises of closer spacing of channels. In most cases, channel splitting is adopted; say from 100 kc/s to 50

kc/s, then to 25 kc/s and so on. This may call for the complete revision of the existing plans, particularly if halving has been used for interleaved channelling. In two-frequency systems some re-adjustment of the frequency separation between the transmitting and receiving frequencies may also be necessary in order to off-set the intermodulation products.

4. **Special Allotments**

When channelling plans are prepared on an international basis, special provisions may be applied to certain channels. For example, channels may be designated for use by specific countries or for specific purposes. For example, in the maritime mobile band the 156.8 Mc/s channel has been allotted for world-wide use as a "distress channel". Similarly, the 121.5 Mc/s channel in the aeronautical mobile band is a world-wide "emergency channel".

5. **Use of Communication Satellites**

Consideration is being given to the use of satellites for the relaying of aircraft VHF communications. If this eventuates, co-channel line-of-sight interference will extend world-wide instead of being only local, and the existing time and distance sharing parameters will need to be reviewed. Similar changes could be extended to the Maritime service.

6. **Preparation of New Zealand Plans**

It has been said that engineering is the application of scientific knowledge with judgement. This paper would thus be incomplete if it did not include some of the non-technical aspects which need to be considered in frequency engineering, in addition to the technical ones outlined above. These additional factors include —

(a) The need to provide for an economic transition from the present usage to an improved state of utilisation. This must take into account the expected life of existing equipment.

(b) The need for a framework to provide for the integration of future national and international plans; and

(c) The desirability of disturbing as little as possible the existing patterns of usage.

7. **Conclusion**

From the above, it will be realised that many factors must be included in the engineering of any plan for the use of very high frequencies for mobile services and that, despite our desire for permanency, any allottment plan must be the subject of constant review. It is only by this means that we can obtain the maximum number of channels within the bands available and thereby meet the explosive demand for more channels of communication.

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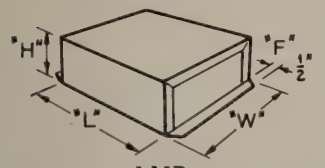

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ELECTRONICS CONFERENCE

The previous article is based on a paper being presented at the national electronics Conference in Auckland in August. This is the first of a number of papers which we have chosen as of general interest to different sections of our readers and which we will publish in the next few months.

Next issue will in fact be away to the printers before the Conference finishes and therefore will include only some selected papers. However, the September issue, due to appear towards the end of that month, will contain a full report on the trade exhibition and new products displayed, a report on the N.E.R.C. discussion and a further selection of papers, together with a brief review of the overall achievement of the Conference.

Whilst we feel it is valuable to have on permanent record some of the activities and papers of the Conference we will not forget readers not catered for by these articles. Extended sources of material for amateurs, hobbyists and students are at present being arranged.

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Properties of the Ionosphere Which Affect H.F. Transmission

The main properties of the ionosphere which affect h.f. radio waves and influence the planning of h.f. communication systems are described. Mention is made of many recently published results and a large number of recent references are given.

by F. R. EAST*

1 THE NATURE OF THE IONOSPHERE

It was not until 1925 that Appleton and has co-workers provided experimental evidence that radio waves were reflected back to earth, instead of travelling out into space, thus proving the earlier contentions of Heaviside and Kennelly that the earth was surrounded by an ionized layer. Appleton went on to establish the existence of several layers at different heights, and subsequent research on a world-wide scale has gradually built up a detailed and extremely complex picture of the behaviour of what is now known as the ionosphere.

There are three main layers of significance, designated D, E, and F, extending upwards into the ionosphere from an elevation of about 60 km (Fig. 1). During the day the F layer separates into the F_1 layer, which lies at an average elevation of 180 km, and the F_2 layer, lying at between 240 and more than 380 km. As the sun declines, the F_2 layer falls and the F_1 layer rises until the two appear to merge and re-form the F layer, at an average elevation of 300 km, which persists until the following sunrise.

The most highly ionized layer, and therefore the most 'reflective', is the F_2 layer, which is subject to the effects of cosmic rays and meteors in addition to corpuscular emissions and ultra-violet radiations from the sun. Evidence of the presence of trapped corpuscular emissions is given by the fact that F_2 ionization is more concentrated in regions about twenty degrees from the magnetic poles, and closely follows the non-uniform distribution of the earth's magnetic field. Fig. 1 reveals that there is also a fairly regular change of height throughout the year according to the degree of expansion due to the heat of the sun.

Fig. 1. Typical daily variations in layer heights for summer, winter and the equinoxes, in the mid-latitudes of the northern hemisphere

The layers below the F_2 are affected by ultra-violet rays of increasing penetrative power (shorter wavelength) but, because of their high gaseous density, have a greater natural tendency to 'de-ionize': that is to say, for the ions and electrons to recombine at a rate corresponding to the increasing rate at which they collide. In every layer the number of electrons per cubic metre is the result of a state of equilibrium between these effects.

Finally, mention should be made of a thin, but highly ionized sporadic-E layer (E_s) which plays an unpredictable, and on the whole minor, role in long-distance propagation. It is liable to be present at all seasons, both by day and, less frequently, by night, and its various causes have still to be determined.

Table I presents the main characteristics of each of the layers mentioned. It should be borne in mind that layer heights and thicknesses vary constantly, whilst the pattern of their distribution and their relative degrees of ionization change daily, seasonally, and in sympathy with the eleven-year sunspot cycle.

TABLE I

Layer designation	Effect on h.f. waves	Approx. height of lower boundary (km)	Average semi-thickness (km)	Period of influence
D	Absorption	60-80	10	Day
E	Refraction	80-100	25	Day*
E^s	Refraction	100	1	Day & Night
F	Refraction	300		Night
F_1	Refraction	180	20	Day
F_2	Refraction	240-400	100-200	Day

* Residual E exists at night, but is of no practical importance.

* The Marconi Company Ltd., England.

2 ABSORPTION

Little of the total ultra-violet energy radiated by the sun reaches the earth's surface because it is expended in ionizing the upper atmosphere. In a somewhat similar way energy from h.f. waves is lost to the ionized layers because the energy interchanged between the waves and the ions and free electrons is given up whenever the latter combine or collide with neutral atoms. It is evident therefore that absorption will tend to be greatest in those regions where the ion density and the rate of collision are greatest. In fact most absorption occurs in the D layer, which lies closest to the earth. Considerably less absorption occurs in the E layer, and very little in the layers above.

It follows that absorption is restricted mainly to the hours of daylight and falls to a low value at night. Its effect in particular circumstances depends upon the length of the radio path, the angle at which it traverses the absorbing region, the time of day, the frequency, and the relative sunspot number. Auroral zones, centred near the magnetic poles, introduce additional absorption in radio paths traversing them.

Below the maximum usable frequency, absorption bears an inverse relationship to frequency. As a general rule: the higher the frequency the less the absorption.

An absorption coefficient, K, has been plotted as a function of latitude, month and local time[1], and from this the absorption loss can be calculated for any circuit by applying a general formula with certain empirically determined constants. Solutions to this formula are available as a set of nomograms, or can be calculated by means of a specially developed slide-rule[2].

Apart from the normal daily variations in ionospheric absorption, it is subject also to sudden increases, termed 'sudden ionospheric disturbances' (s.i.ds.) or Dellinger fades, which seriously affect communications. These occur most frequently during periods of maximum sunspot activity, being caused by solar flares which enhance the intensity of ultra-violet radiation for periods lasting from a few minutes to several hours. On an average circuit up to 2% of the daylight operating time[3] can be lost from this cause at sunspot maximum (Fig. 2).

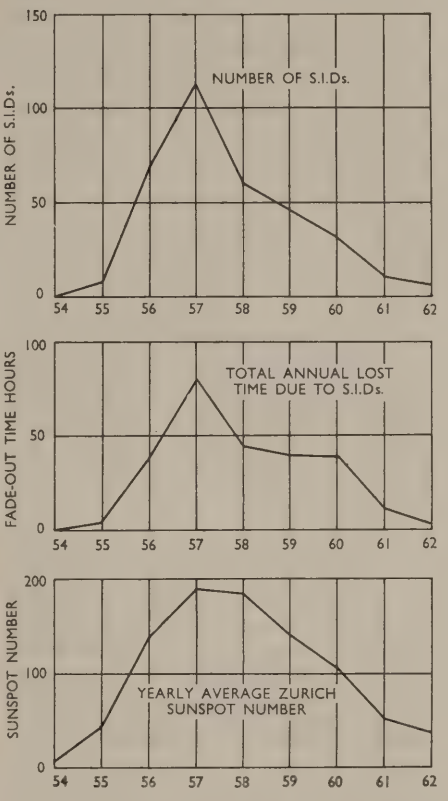

Fig. 2. Circuit time loss due to sudden ionospheric disturbances (s.i.ds.) during the period 1954-1962, as reported by Post Office receiving stations at Brentwood and Somerton in England. During 1957 (a year of maximum sunspot activity) time lost was approximately 84 hours, corresponding to 2% of the daylight period, whereas during 1954 (sunspot minimum), no s.i.ds. were reported. The average duration of s.i.ds. tends to be longer when their occurrence is infrequent.

Within thirty-six hours of a solar flare a geomagnetic storm, caused by corpuscular radiations travelling more slowly than light, may also develop. This again causes abnormal absorption and at the same time reduces the density of the F_2 layer, thus lowering its critical frequency (see Section 3). Recovery takes place in a matter of days, rather than hours, and the effect on communications is altogether more serious. Fortunately, magnetic storms are much less frequent than solar flares.

Solar disturbances are difficult to predict, although progress has been made in recent years by correlating visual observations of flares with various types of solar radio emission[4]. Recently, close correlation between flares of all magnitudes and a sudden increase in long-wave field intensity (s.i.l.), due to the increased ionization of the D layer, has been reported by Mitra[5], with tentative suggestions for a new type of international flare patrol capable of giving reliable short-term warnings.

3 REFRACTION

As far as propagation is concerned, the all-important effect of ionization is to reduce the refractive index, μ, of the ionosphere, thus causing the refraction (or apparent reflection) of radio waves in accordance with Snell's optical law:

$$\mu = \frac{\sin i}{\sin r} \qquad (1)$$

where i and r are the angles (to the normal) of incidence and refraction respectively.

The refractive index of the ionosphere is a function of the frequency, f, of the wave and of a factor, D, which is proportional to the density of ionization:

$$\mu = \left(1 - \frac{D}{f^2}\right)^{\frac{1}{2}} \qquad (2)$$

It can be seen that, for a given frequency, μ decreases as the density of ionization increases as the wave approaches the centre of the ionized layer. From Equation (1), at a certain value of μ, depending on the angle of incidence, sin r = 1 and r = 90°. This makes the path of the wave normal to the earth's radius and further refraction will cause the wave eventually to leave the ionized layer at the same angle as the angle of incidence.

In the special case of a vertically incident wave, μ must reach a value of zero for the wave to be returned to earth. The highest frequency at which this occurs in a given layer is called the critical frequency, f_0, of the layer. From Equation (2),

$$\mu = \left(1 - \frac{D^{max}}{f_0^2}\right)^{\frac{1}{2}}$$

$$\therefore f_0^2 = D^{max}$$

where D^{max} is the maximum density of ionization in the layer.

From a knowledge of the critical frequency of a layer, the highest frequency at an oblique angle of incidence, i, which will be returned

to earth can readily be calculated. Since $r = 90°$, $\sin r = 1$ and

$$\sin i = \mu = \left(1 - \frac{f_0^2}{f^2}\right)^{\frac{1}{2}}$$

$$\therefore \sin^2 i = 1 - \frac{f_0^2}{f^2}$$

$$\therefore \cos^2 i = \frac{f_0^2}{f^2}$$

$$\text{and } f = f_0 \sec i$$

This is the well-known Secant Law which is continually used in choosing operating frequencies for a given circuit. It is only strictly true for a flat earth and a flat layer, and must be modified for accurate calculations.

The velocity of the energy in a wave, and approximately that of the signal, is known as the group velocity, c^g. It is less than the velocity of light, c, since $c^g = \mu c$. In the case of a vertically incident wave, μ and hence c^g become zero before the wave is returned to earth. The reduction in the velocity of propagation is generally ignored in vertical incidence sounding and the 'virtual height', h', is calculated from the time delay, t, before the echo is received, using the expression: $h' = \frac{1}{2}tc$.

4 MAXIMUM USABLE FREQUENCIES

The basis for all frequency planning is the layer critical frequency, and measurements are collected systematically by ionospheric sounding centres throughout the world. The practical parameter, however, is the maximum usable frequency, or m.u.f., of which there are several definitions[6]. In each case m.u.f. designates the highest frequency which, in a particular set of conditions, can be used to propagate radio waves over a given route.

Predictions of f_0 and m.u.f. for the lower layers can be obtained from charts for any given sunspot number and a knowledge of the sun's elevation, since they are solar-controlled. The m.u.f. applying to the F_2 layer is not so easily determined, because it obeys more complex laws and its correlation with solar activity and geographical factors is not so close.

It is necessary, therefore, to present predictions in the form of world charts showing contours of monthly median values of m.u.f. for several months in advance. These are based on an F_2-region ionization index, I^{F_2}, devised by Minnis and Bazzard[7, 8] from data collected by observing stations in various parts of the world.

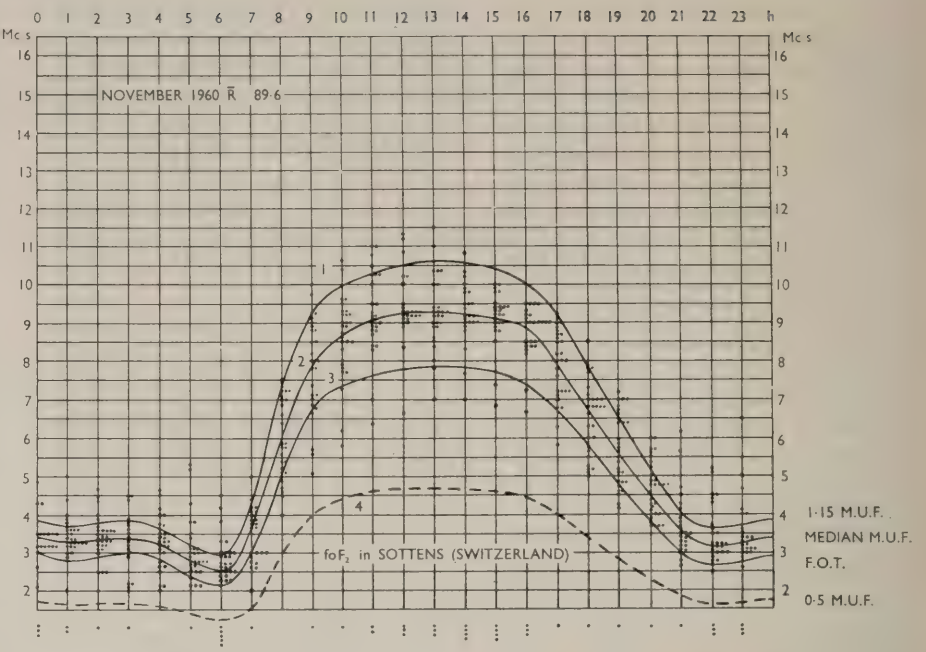

Fig. 3. A plot of hourly vertical incidence soundings of the F_2 layer made at Sottens Observatory, Switzerland, for the thirty days of November 1960. On each time ordinate there are thirty points representing the daily measurements of critical frequency, f_0. R = 89.6 is the 12-month running average sunspot number

Charts issued in Britain by the Radio Research Laboratory, Slough, cover both F_2 critical frequency and the 4 000 km median m.u.f. for every even hour (Greenwich mean time) of the day. Computations based on the latter would be statistically reliable for only 50% of the days, and it is normal to adopt an f.o.t (optimum traffic frequency) 15% lower than the m.u.f. to ensure reliability for approximately 90% of the days. Fig. 3, due to Garcia Rios[9], shows in a striking manner the spread of F_2 critical frequencies during a thirty-day period. From the number of points above each curve on each of the time ordinates it is possible to determine the number of days on which a given frequency would have been refracted.

By definition, the median m.u.f. curve will have an equal number of points above and below it, indicating that signals would have been refracted for fifteen of the thirty days (more, where several points lie on the curve). Similarly, it may be seen that between 80 and 90% of the points lie above the f.o.t. curve (No. 3), which is 15% below the median curve, whilst at the other extreme an average of about 10% lie above the curve (No. 1) of frequencies 15% greater than the median m.u.f.

5 LOWEST USABLE FREQUENCIES

Just as upper frequency limits are imposed as a direct consequence of layer ionization and path geometry, so too there are lower frequency limits, known as lowest useful high frequencies (l.u.fs), although they arise from entirely different considerations.

The l.u.f. is related to the minimum signal strength required for reception, and is therefore governed by a number of factors, some of which are subject to engineering control. Among the latter are the transmitter power and associated antenna gain, and the directivity of the receiving antenna. In so far as there may be freedom to choose a receiving site remote from sources of man-made noise, such noise is also subject to a degree of control.

Path attenuation, due to absorption, and the incidence of atmospheric noise (apart from its relation to antenna design), are not subject to control and constitute the major factors affecting the lower limit of

usable frequency, since both increase as frequency is reduced.

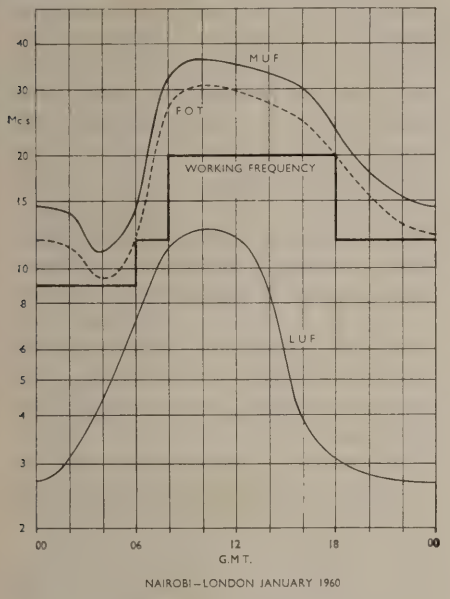

Fig. 4. The diurnal variation of expected condtiions on a typical route

Required field intensity varies with the type of service (C.C.I.R. Recommendation No. 339)[10] and is one of the important parameters of the l.u.f. curve, the other being the ionospheric index (or the relative sunspot number) to which daily absorption is related. Typical daily variations of ionospheric conditions, including m.u.f, f.o.t, and l.u.f. are shown in Fig. 4. It may be seen that during the early part of the day the band of available frequencies is narrow. In conditions approaching the sunspot minimum it frequently happens on certain circuits that the l.u.f. exceeds the m.u.f, thus making h.f. communication impossible unless the transmitter power can be increased.

6 FADING

Fading necessitates the transmission of a great deal more power than would be required in stable conditions. Some forms of fading cause distortion in telegraphy and telephony transmissions, thus making the design of receivers and terminal equipment more complicated and increasing their cost.

The four main causes of fading are:

a) Absorption } rapid
b) Skip zone variation }
c) Wave interference } slow
d) Changes in polarization }

Slow fading covers day-to-day variations in signal strength, and rapid fading covers those which occur within periods of the order of seconds or less. In practice, of course, the two forms occur together.

6.1 Slow Fading

Median signal intensity is chiefly dependent upon the length of the radio path and the number of ground reflections, but if it may be assumed that for a given circuit these factors remain constant, there will still be daily variations due to absorption in the D layer and, to a lesser extent, in the E layer.

Superimposed on these are random daily variations, and others related to the season and the degree of solar activity. Long-term measurements have shown that, for a given hour on a given circuit and frequency, the upper decile of hourly median values is unlikely to be more than 10 dB above the median monthly value for the same hour. Putting this another way, for a given time of the day it may be expected that during any period of thirty days there will be less than 10 dB difference between the signal strength exceeded on fifteen days and that exceeded on only three days.

Fading should not be considered in isolation from noise. Being the result of a multiple transmission from regions of high thunderstorm activity, noise is subject to the same variations as other types of signal. Moreover, in practice, an increase in noise is equivalent to a signal fade, and the two must therefore be considered together.

It is assumed that in the worst case likely to occur there would be no correlation between the variations of signal and of noise, and that a good estimate of the combined variations can be obtained by taking the root mean square of two 10 dB factors:

$$\sqrt{(10^2 + 10^2)} = 14 \text{ dB}$$

It follows that in arriving at estimates of the minimum signal-to-noise ratios necessary for various types of service a slow-fading safety factor of 14 dB should be added in every case (see C.C.I.R. Recommendation No. 340)[11].

6.2 Rapid Fading

Because of the irregular and unstable layer structure of the ionosphere, h.f. signals propagated by this medium tend to separate along a number of simultaneous paths to arrive at the receiver as a group of independent signals with random phase relationships.

Not only does the resulting wave interference cause wide fluctuations (up to 30 dB or more) in signal amplitude, but the time-spread between first and last significant arrivals becomes a limiting factor[12] in high-speed telegraphy reception.

Depending upon the nature of the signal, the amplitude distribution of rapid fading may appropriately be regarded as having either a log-normal or a Rayleigh type of distribution. Assessed over periods of a few minutes, the fine structure appears to follow the Rayleigh Law. Calculations of safety factors for automatic high-speed telegraphy are accordingly based on the assumption of this type of distribution, whereas those for hand-speed morse, telephony and other forms of signalling, are based on a log-normal distribution, taking the empirically derived figure of 7 dB as the ratio of median level to that exceeded for 10% or 90% of the time.

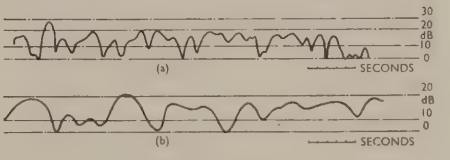

Fig. 5. Oscillograph records of the rapid fading of single-frequency signals, the total excursions being covered within a few seconds, received in the United Kingdom from (a) Shepperton, Australia, 27 October, 1954. 1410 G.M.T. 11 900 kc/s, and (b) Sackville, Canada, 7 October, 1954, 1358 G.M.T. 15 090 kc/s

Fading rate may be considered as the frequency of successive crossings in the same direction of a given amplitude ordinate (Fig. 5) and has been found to reach its maximum at the most probable amplitude. This maximum has been termed the quasi-frequency of fading, and its reciprocal the quasi-period[13]. Among the many factors affecting its value are the route length and the number of hops, the operating frequency, and the angle of incidence with the ionosphere.

From a series of tests over medium and long distances, at frequencies between 6 Mc/s and 18

Mc/s[14], the mean fading speed (excluding a number of exceptionally high fading time-constants on one circuit) was found to be 2 seconds. With very distant transmissions the fading time, averaging 0.56 second, was most consistent; but over relatively short and intermediate distances there were spreads between less than 0.5 second and more than 5 seconds.

7 MULTI-PATH DELAYS

It is evident from ionograms (i.e. oscillographs of ionospheric soundings) recorded for many different routes that multi-path delays are least at frequencies close to the m.u.f, and increase to a maximum at frequencies appreciably lower. Delays lie typically between 0.5 and 4.5 milliseconds, and are most easily observed by reference to radio facsimile charts[15], in which straight lines normal to the line of scan bear a superimposed ripple, the width of which is proportional to the difference in propagation time of the shortest and longest paths that predominate from instant to instant. Results of an analysis of 1600 facsimile charts received from Washington and Japan during the period June-September, 1961, are given in Fig. 6.

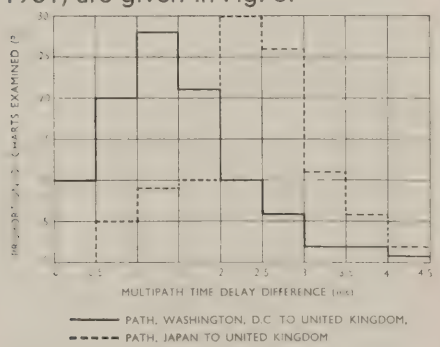

Fig. 6. Incidence of multi-path delays from an analysis of fascimile charts transmitted on two meteorological broadcast services

The observed relationship between multi-path delay and the ratio of the m.u.f. to the operating frequency led D. K. Bailey to the concept of a multi-path reduction factor (m.r.f). This is the smallest ratio of m.u.f. to operating frequency for which the time delay is less than a specified value, and defines the frequency above which a stated minimum protection against multi-path is provided. Bailey's m.r.f. included only F_2 reflections, and various simplifying assumptions. Subsequently, Salaman[16] derived m.r.f. predictions based on experimental data which took into account propagation by all modes (including sporadic-E) and other known factors relating to multi-path propagation. His curves, shown in Fig. 7, are estimated to be correct within 15%.

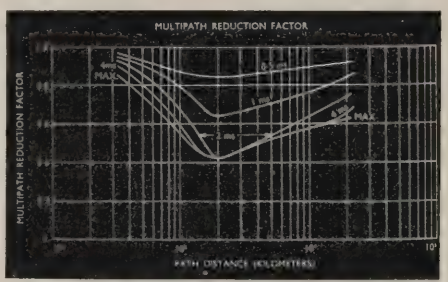

Fig. 7. Multi-path reduction factors, based on experimental data, for various values of time delay plotted against path distince

From these it may be seen that, for a path length of 2500 km, the multi-path delay will be less than 0.5 ms when the operating frequency is not less than 85% of the m.u.f. Between 85% and 65% of the m.u.f. the delay will lie between 0.5 and 1 ms, and will rise towards a maximum of 2 ms as the frequency falls to 43% of the m.u.f.

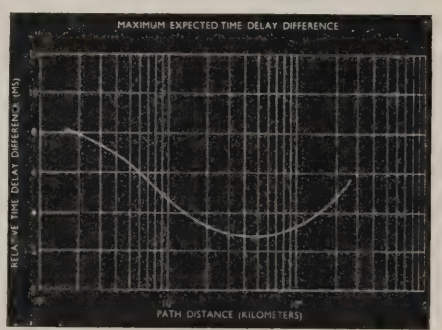

Fig. 8. Maximum expected time delay plotted against path distance

From Fig. 8 it may be seen that maximum multi-path delays are likely to be greater over short routes, and from Fig. 7 that for short routes a frequency close to the m.u.f. must be used. To take an extreme example, the multi-path delay over a distance of 200 km could be as much as 8 ms, equivalent to 40% distortion at a keying speed of 50 bauds, when operating with a frequency only 10% below the m.u.f.

8 CONCLUSIONS

A vast amount of investigation, both practical and theoretical, has progressively improved our knowledge and understanding of the properties of the ionosphere, increasing the accuracy with which h.f. transmission systems can be planned. The limits of uncertainty have been narrowed and areas where further research is required are clearly defined. Although our knowledge of transmission modes, tilted layers, and of the occurrence of sporadic-E, for example, is still less than adequate, further significant advances in h.f. transmission would seem to lie in improvements in engineering technique rather than in any more complete understanding of the ionosphere.

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SERVICEMAN'S COLUMN

Conducted by

J. WHITLEY STOKES

A question frequently asked by TV owners is — "How long should a set last?", and as manufacturers are rather reticent on this point servicemen naturally find difficulty in giving a satisfactory reply. To my knowledge only one manufacturer has been bold enough to make an official pronouncement regarding life expectancy and even so does not use it as an advertising feature.

This fact is not really to be wondered at and is not confined to TV manufacturers. (After all nobody advertises a motor car which will last for a specified number of years). The one manufacturer referred to states that his sets are estimated to have a life expectancy of ten years. This figure is presumably an average one and will be tied up with maintenance costs during the period. As with most 'consumer durables' there comes a time when more frequent and increasingly expensive repair costs reach the stage where trading-in becomes the more acceptable alternative.

These musings were brought on by recent happenings; firstly a customer had brought in two identical chasses (plural of chassis, if anyone doesn't know) for repair. Actually there was one complete set and one chassis, the former being of the consolette variety, could be transported (minus legs) in the boot of his car, while the latter was from a large console model. As it happened they both were 90° models of the same make and age, which in itself was something of a concidence as there were very few 90° ever made in this country.

The consolette, I was informed by the owner, was a recent acquisition, having been purchased in "as is" condition from a neighbour, whereas the chassis from his big set was quite familiar to me as I had been looking after it for the past six years.

In contrast to servicemen, to the factory man anything out of the guarantee period is 'old'. Still, six years is quite a long time, and irrespective of the amount of use a receiver has had in that period, a certain amount of general deterioration is inevitable. The question then was, could these two sets be classified as old? Certainly they were two of the first ever made in this country yet would a radio or gram of similar age be considered old? Although the answer to this question depends largely on the general condition of the article as distinct from its actual age in years, I think most radio owners would not hesitate to spend money on repairs to a six year old receiver whereas the TV set owner, depending of course on his previous repair expenses would hesitate to spend more than £10.0.0 or so on a six year old receiver.

This raises another point — do TV receivers wear out more quickly than radios? Bearing in mind the more frequent and more expensive repairs needed in the case of TV the answer to this question must be yes.

To return to the two receivers under discussion, the owner's first set which had cost him very little for repairs over the years was automatically assumed by him to be worth repairing and I was given carte blanche in this connection. As regards the newly acquired consolette, here too the owner was prepared to let me go ahead regardless but I was immediately doubtful of the wisdom of doing so until I had had a preliminary look-see. For one thing I noticed that someone had poured liberal quantities of cellulose cement into the slug adjusting holes of the I.F. coils. So liberal in fact was the application of cement that it had completely filled up the holes and run over on top of the coil cans in some cases. Of course this stuff sets rock hard and it was obvious that this thoroughly reprehensible act had made future adjustments impossible. I could only hope for the owner's sake that the alignment was good enough as it now stood, because if it wasn't it meant that the thing was virtually a write off.

Further investigation revealed a 'no raster' condition, caused by a dud line oscillator valve together with a missing booster diode. However even when the raster was restored it was barely visible with the brightness control fully advanced. Things weren't looking too good — a weak picture tube as well — and still no picture. Temporarily hooking up a C.R.T. filament booster brought the brightness up to normal but the lack of signal still had to be investigated. Here the trouble was quickly traced to the tuner. With a lot of careful juggling with the switch shaft it was possible to get some sort of picture together with buzzy sound. At this stage I had to decide whether the poor video response was due entirely to the defective tuner or whether the IF section was contributing to the trouble. A check of the I.F. response curve should settle the question and with the sweep and marker generator hooked up it was soon found that the curve displayed on the 'scope which looked OK at first glance was far from being correct. The main fault was that the 34.4Mc sound plateau was much too high up the slope, being located near the knee of the curve and by the same token the 33.4Mc point instead of being down in the trap was also well up the curve. No wonder the sound buzzed!

After considering all the above points I decided that the chassis should be classified B.E.R. (Beyond economic repair) and informed the owner accordingly.

To me the most interesting aspect of the two cases was that, with two identical model sets of the same age, one was still good for many years service yet the other was now a write-off. How come? Unlike a motor car which, within a given period, can be 'run into the ground', a TV set can only be used for a maximum of five hours or so daily. Could the difference between say 2 hours and 5 hours nightly viewing be responsible for the big difference in the condition of the two sets? What do you think?

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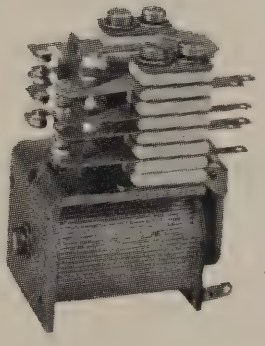

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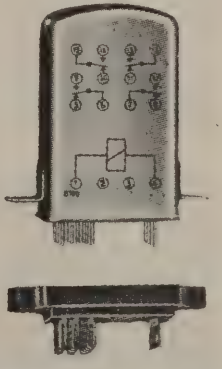

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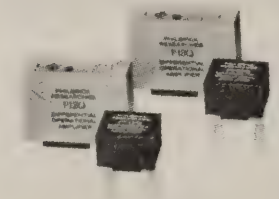

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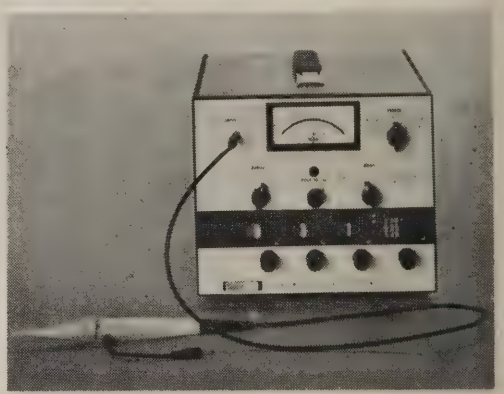

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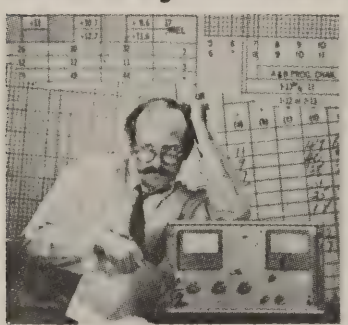

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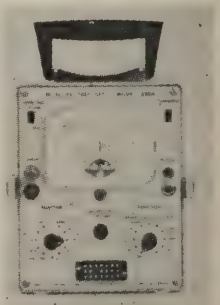

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Continued from page 20

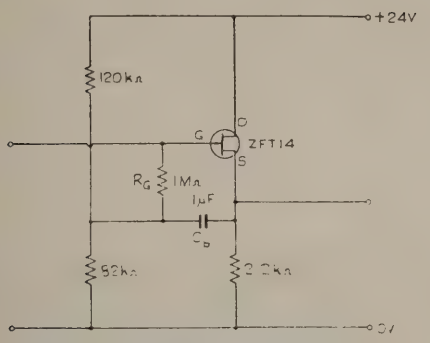

Fig. 17. With bootstrap capacitor

is used in order to illustrate clearly the effect of bootstrapping. The value of C^b is important in that maximum improvement is achieved when the reactance of C^b is small at the lowest frequency concerned.

$$R = 1M\Omega$$
$$R^{in} = 5.5M\Omega$$
$$C^{in} = 7.7pF$$

It is clear that bootstrapping increases the input impedance considerably and so allows a greater range of impedance levels with better stability of performance.

In the circuit shown in Fig. 18 a further increase in input impedance is achieved by means of negative feedback.

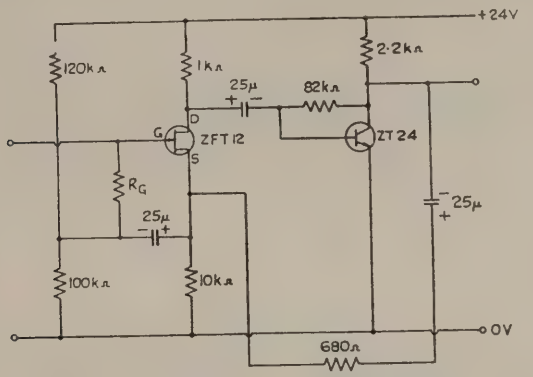

Fig. 18. Application of negative feedback

The first stage is a high input impedance F.E.T. amplifier with a drain load. The gain of this stage is well below unity. The output of the F.E.T. is coupled to a high gain amplifier using a conventional 'bipolar' transistor. Almost the entire output signal of this stage is fed back to the source of the F.E.T. This large amount of negative feedback has the effect of increasing the input impedance of the complete amplifier over and above that of the F.E.T. first stage.

The amplifier has unity gain and input resistance and input capacitance as follows:–

$R^G = 1M\Omega$	$R^G = 10M\Omega$
$R^{in} = 65M\Omega$	$R^{in} = 500M\Omega$
$C^{in} = 4.5pF$	$C^{in} = 4.5pF$

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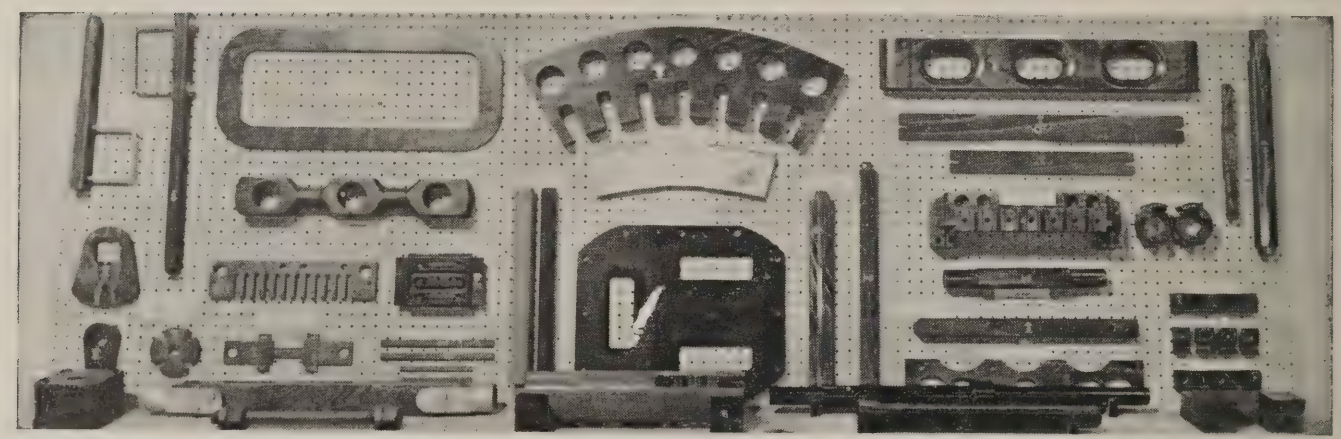

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INVESTIGATIONS OF VLF PROPAGATION

Continued from page 16

ling in two or more different modes in the waveguide.

This was given strong support by work done by Crombie[6] using transmissions from NPM (Hawaii) received at Boulder and NBA received in Frankfurt in Germany. Long path interference would be most unlikely in these cases. The observed steps in the sunrise and sunset phase transitions were closely correlated with pronounced amplitude fades. This fitted well with a propagation model in which the transmission in the daylight waveguide is predominantly in one mode, but in the night-time path is in two separate modes with different rates of attenuation and propagation velocity.

Kaiser, of Victoria University, working at the Physics and Engineering Laboratory, has very recently produced a paper[7] in which he shows that the phase and amplitude results at Lower Hutt from NPG on both 18.6 and 24 kc/s and from WWVL on 20 kc/s agree with the Crombie model, and in particular, that the sunrise cycle losses can be so explained. Figure 4 shows the stepped phase shifts and amplitude variations which occur.

The extent to which the long great circle path signal can cause interference has yet to be thoroughly investigated. Barber and Crombie[8] showed that the earth's magnetic field has a significant effect on the attenuation of VLF signals. Signals travelling from west to east at large angles to the magnetic field are considerably less attenuated than those travelling east to west. Thus it can be explained that the long path signal (28,000 km) from NBA to New Zealand can be at times stronger than the short path signal (12,000 km). The short path arrives at the receiver at an angle of about 75° to the magnetic field. Observations on NSS, Washington (15.5 kc/s) some years ago, showed that the long path signal (26,000 km) was sometimes received in New Zealand at strengths similar to the short path signal (14,000 km). This signal arrives at an angle of about 48° to the magnetic field.

It might be expected that the east-west magnetic effect would not favour the NPG long path signal to New Zealand (19° to the field lines) but WWVL to New Zealand has a path about 33° to the field, and the relative short and long path signal amplitudes would be worth investigating.

IRREGULAR VARIATIONS

There are from time to time various geophysical events, both naturally occurring and man-made which can disturb the lower ionosphere and so produce VLF phase and amplitude variations. The total solar eclipse of May 1965 began at sunrise in the vicinity of North Auckland and the totality zone swept across the Pacific.

The WWVL and NPG signals received at Lower Hutt showed significant phase lags indicating a return to night-time conditions over parts of the paths. The phase lag was of the order of 10% of the normal diurnal shift and the times of the maximum retardation agreed fairly well with the times of transit of the totality zone across the radio paths. Any effects on the signals from GBR to Auckland and Lower Hutt were too small to be measured. These paths were estimated to be close to the beginning of the totality region.

Solar flares almost always are accompanied by a burst of X-rays in wavelength band $\frac{1}{2}$ to 4°A. These will produce an increase in low level ionisation over a considerable area of the earth's surface centred on the sub-solar point, and any VLF path traversing this region is likely to experience a sudden phase advance. In fact, the sudden phase anomalies (S.P.A.) recorded over a short VLF path provide a very sensitive indicator of the occurrence of solar flares. No work is being done in New Zealand on this at present, although the solar flare of 23 February 1956 which was of outstanding magnitude, was observed at Lower Hutt as affecting signals from GBR, and the results of the observations were published[9].

The detonation of high power nuclear devices in the atmosphere can be expected to cause large ionisation changes which will produce SPA's on VLF signals. Several of the Johnston Island high level explosions in 1962 produced phase and amplitude effects on VLF signals across the Pacific. In particular, the large event on 9 July produced very large and sudden phase shifts. The GBR signal received at Lower Hutt was suddenly advanced about 720° in phase, and the NBA signal by about 630°, corresponding to a lowering of the night-time ionosphere height over the whole Pacific by about 17 km.[10] It is presumed that this was produced by an intense burst of X-rays analogous to the daytime solar flare effect.

The expected French nuclear tests at Mururoa will be reasonably close to the path from WWVL to Lower Hutt. Careful observations will be made during these tests. It is not expected that the effects will be large unless the detonation is at high altitude. The ionisation effects would depend on the size and nature of the device — an explosion with a heavy yield of high energy neutrons would be expected to produce a significant ionisation change and a detectable phase variation on VLF paths across the mid-Pacific.[11]

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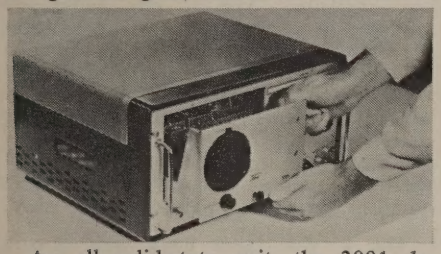
ENQUIRY 349. USE FORM AT REAR.

New Products

PLUG-IN OSCILLATOR SWEEPS 180 MHz

A solid-state oscillator with frequency coverage of 50 to 230 MHz, and capable of sweeping its entire range is now available from W. and K. McLean, representing Telonic Industries.

Designed as a plug-in unit for the Telonic SM-2000 sweep generator chassis, the new oscillator Model 3001, is capable of providing frequency response data for testing, aligning and check-out of narrow or broadband devices such as VHF television circuits, FM broadcast equipment, aero and radio navigational gear, filters and attenuators.



An all solid-state unit, the 3001 develops an output that is fundamental, thereby providing a 1v RMS signal of exceptional purity and stability. The oscillator itself is electronically swept and tuned by means of varactors. Its low level output voltage is fed to an operational amplifier that supplies the proper output level and also provides the leveling function.

Sweep width of the 3001 oscillator may be varied continuously from 0.25% of centre frequency at a 60 Hz sweep rate to the full 180 MHz range of the unit. The sweep rate is also variable from 0.01 Hz to 100 Hz. Linearity is an excellent 1.5:1 at maximum sweep and 2.0:1 at 10% of maximum. Flatness is specified at ±.5 db.

Mechanically, the new oscillator is of modular construction to simplify maintenance. A single circuit board for 8 plug-in modules and 2 replaceable RF modules constitute the entire circuitry. Front panel controls include the centre frequency dial and a variable frequency marker.

ENQUIRY 321

* * *

100 Mc/s INTEGRATED CIRCUIT WIDEBAND AMPLIFIERS

A new series of monolithic, silicon, integrated circuit, wideband amplifiers, claimed to be the most advanced in the world, have been announced.

The amplifiers are intended for use in I.F. strips operating between 10 and 60 Mc/s and have current gains of X20, an upper cut-off frequency of 100 Mc/s and a noise figure of about 6dB. Unique features are the inclusion of supply line decoupling networks and wide range A. G. C. facilities. The circuits operate over the full military temperature range of −55°C to +125°C.

ENQUIRY 301

DC STANDARD/DIFFERENTIAL VOLTMETER

DC voltage accuracy is specified at 0.002% in Hewlett-Packard's new Model 740B DC Standard/Differential Voltmeter. The 740B has 6 digital places, available in discreet steps to 1 ppm resolution including the incorporation of a digitally-calibrated standard vernier. In keeping with trends toward better electromagnetic compatibility, radio-frequency interference characteristics have been improved, the new instrument fully complying with MIL 6181D.

As a dc standard source, HP Model 740B produces output levels from 0 to 1000 volts. Under standard measuring conditions, accuracy is ± 0.002% of setting + 0.0002% of range. Accuracy remains exceedingly high ± 0.005% of setting + 0.0002% of range, even with temperature variations from 15° C to 35° C. These levels of accuracy are maintained for at least 30 days without recalibration. The instrument will deliver current up to 50 ma, the current limiter adjustable from 5 to 50 ma. The output circuit is floated and guarded.

As a differential voltmeter, the unit has 0.005% accuracy. Floated and guarded input terminals present more than 1000 megohms input resistance on most ranges. This value remains constant regardless of null condition, thus eliminating loading of the measured circuit when off null, and removing the consequent potential errors.

ENQUIRY 312

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BROAD-BAND TELEVISION AMPLIFIER

Flats, hotels, institutions and home units are but some of the possible locations for this broad-band television amplifier which can distribute television signals to 40 receivers, with only one antenna. The unit is entirely self contained. It can be hung vertically on a wall or shelf-mounted. It has a universal input to accept single channel yagis or broad band antennae at 300 or 72 ohm impedance. In weak signal areas or where the antenna is installed at a distance from the viewer, the units can be cascaded or used with another amplifier by the same manufacturer. There are separate adjustable gain controls for low and high band.

Specification:
Gain: 35 dB over 1 channel; 25 dB all band.
Flatness: ± 1¼ dB.
Noise Figures: 6 dB low band; 7.5 dB high band.
Recommended min input for snow-free pictures: 500 microvolts.
Max output: 100 millivolts.
Input impedance: 300 ohms balanced and/or 72 ohms unbalanced.
Output impedance: 72 ohms.
Valves: 3 x 6BQ7A, 1 x 6CB6, 1 x Ak5.
Power Mains: 200-250v — 50 cycle a.c. — 35 watts. Unit may be on continuously.
Dimensions: 12⅛ x 5⅝" x 4⅜".

ENQUIRY 328

* * *

VALVE TESTER

Provides rapid mutual conductance measurement on more than 7,000 valves, British, American and Continental, with up to 12 pins and with a maximum power dissipation of 25 watts. Also tests CRTs (including colour TV tubes). New edge control circuit selector switch connects any valve pin to any electrode. Checks diodes and rectifiers for emission under normal working conditions with a load test for high current rectifiers. Tests each section of frequency changer and other multiple valves separately for mutual conductance and emission. Ten valve bases, including Compactron and Nuvistor types; a B14E base accepts a range of adaptors to cover any obsolete or new base not already incorporated. Tests most CRTs without removing tube from receiver with adaptor which can be supplied.

ENQUIRY 333

* * *

NEONS

'Brightlife' neons give great brightness and 25,000 hrs. average life, all being of the high intensity type. All can be operated at 120°C. at panel, 75°C. at leads. Even higher temperature versions are available. The ⅜" dia. neons are moulded in polypropylene which diffuses the light and the ⅝" dia. are moulded in polycarbonate which gives higher light transmission. Both types give a glow behind the panel to warn maintenance staff. Units are one hole fixing ½" or ⅝" dia. clearance and a thin protrusion prevents rotation and may be fitted to a notch in the side of the hole or crushed.

The ½" dia. types have high density polythene bases with the leads moulded in, this giving a unit of high chemical resistance which is splashproof. For ease of installation the neon is pulled out of the housing and the housing supported on a flat surface, pushing ring over with short length of tube (supplied on request). The base and neon are then replaced without bending neon or resistor wire.

ENQUIRY 337

Our radio broadcast universal replacement coils will replace any damaged aerial, R.F. or oscillator coil. Designed to assist you in maintaining first-class service to your clients.

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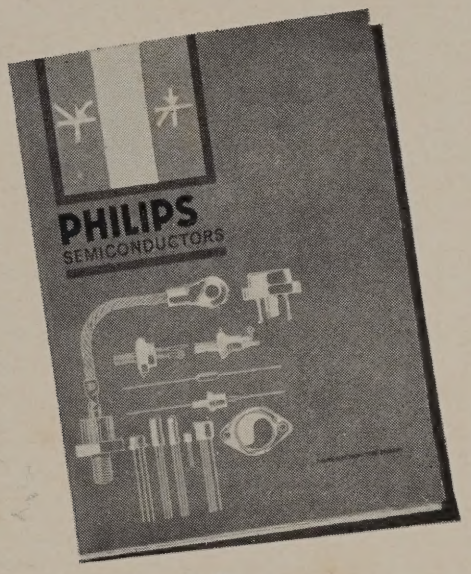

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